COMMONWEALTH OF MASSACHUSETTS

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PRIVATE WELL GUIDELINES

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INTRODUCTION

A private water supply provides water for human consumption and consists of a system that has less than fifteen service connections and either (1) serves less than twenty-five individuals or (2) serves an average of twenty-five or more individuals daily for less than sixty days of the year. In the Commonwealth of Massachusetts over 500,000 people rely on private water systems to provide potable water because public water systems are not available to serve them.

The improper design, construction, repair, maintenance, or decommissioning of a private water supply system represents a potential hazard to public health and safety. In order to protect the health and general welfare of the citizens who depend on private water supply systems and to protect the groundwater resources of the Commonwealth so that the consuming public can be assured of potable water, it is necessary for regulators to know what constitutes a private water supply system and understand the measures that should be taken to protect the water supplied by the system.

The Private Well Guidelines and accompanying Model Board of Health Regulations for Private Wells were written primarily to assist Boards of Health but also to assist drillers by attempting to introduce some consistency regarding construction standards from town to town. The Private Well Guidelines also provides information useful to the private well owner, developers, and interested local officials.

The Model Board of Health Regulations for Private Wells provides general guidance because subsurface geology varies across the Commonwealth. Well construction and water quality concerns on Cape Cod, for example, differ substantially from those in western Massachusetts. The Private Well Guidelines, on the other hand, is a more comprehensive reference and provides detailed information regarding well construction in addition to discussion of issues concerning local groundwater protection and water quality. Because the Private Well Guidelines is intended as a reference, it was written with a built-in redundancy.

Although these guidelines contain information that is applicable to private water supply systems that derive water from surface water sources, the primary focus is on systems that utilize a well to obtain groundwater.

Household irrigation wells have become an issue recently because of the dramatic increase in water rates in parts of Massachusetts. The well construction requirements recommended in the Private Well Guidelines and the Model Board of Health Regulations for Private Wells could be applied to irrigation wells. However, if the wells are used strictly for irrigation, some of the recommended water quality testing requirements are too stringent.

Neither the Private Well Guidelines nor the Model Board of Health Regulations are a substitute for existing regulations and statutes.

SUMMARY OF LAWS AND REGULATIONS APPLICABLE TO PRIVATE WATER SUPPLY SYSTEMS

Although the Commonwealth of Massachusetts does not have any statutes that specifically regulate private water supply systems, there are a number of laws that indirectly protect the quality of the water obtained from a private water system. This section summarizes existing laws and regulations that are applicable to private water supply systems. Regulations developed pursuant to the Massachusetts General Laws (MGL) are contained in the Code of Massachusetts Regulations (CMR) and can be purchased individually from the State House bookstores in Boston and Springfield.

STATE JURISDICTION

Department of Conservation and Recreation

Chapter 21, Section 11 of the Massachusetts General Laws authorizes the Division of Water Supply Protection to "establish rules and regulations necessary for the proper administration of sections nine to sixteen, inclusive." **Section 16** requires any person engaged in the business of digging or drilling wells within the Commonwealth to register annually with the Division of Water Supply Protection. It also states that "within thirty days after completion of any well by digging or drilling, the person engaged in the business of digging or drilling wells shall submit a report to the Commission setting forth such information as may be required under said rules and regulations."

The regulations developed by the Division of Water Supply Protection pursuant to MGL Chapter 21, Sections 11 and 16 are contained in **313 CMR 3.00, "Water Well Diggers and Drillers Registration."** These regulations (1) provide the criteria necessary for the registration of well diggers and drillers in the Commonwealth of Massachusetts, (2) establish the information that must be furnished as a prerequisite for registration, (3) establish the information that must be submitted to the Division of Water Supply Protection upon the completion of any well, and (4) set forth penalties, including revocation of registration, if a driller is found to be in noncompliance with state or town regulations.

Department of Environmental Protection

In **Chapter 111** of the Massachusetts General Laws. the Department of Environmental Protection (DEP) is granted general responsibility and authority for protecting drinking water supplies within the Commonwealth. Specifically, **Section 159** confers upon the DEP "the general oversight and care" of all waters used by any municipality, institution, or person in the Commonwealth as a source of water supply. In **Section 160**, the DEP is authorized to "make rules and regulations and issue such orders as in its opinion may be necessary to prevent the pollution and to secure the sanitary protection of all such waters used as sources of water supply and to ensure the delivery of a fit and pure water supply to all consumers." **Section 5G** states that the DEP "may require by order a city, town, person or district maintaining a water supply to provide and operate such treatment facilities as are in its opinion necessary to insure the delivery of a safe water supply to all consumers."

In order to protect underground sources of drinking water as required in the Federal Safe Drinking Water Act, and pursuant to MGL Chapter III, Section 160 and MGL Chapter 21, Section 27, the DEP promulgated **310 CMR 27.00, "Underground Water Resource Protection**." These regulations prohibit the underground injection or disposal of hazardous wastes, and fluids having the potential to contaminate groundwater. In addition to the requirements provided in 310 CMR 27.00, **MGL Chapter 21C, Section 5** states that no person shall dispose of hazardous waste "in a manner which could endanger human health, safety or welfare, or the environment." In accordance with MGL Chapter 21C, Section 5 and 310 CMR 27.00, it is illegal to use a private water supply well, test hole, or dry or inadequate boring as a drain or disposal receptacle for any fluid or material including, but not limited to, sludge, solid waste or trash, and waste oil or other hazardous waste.

Chapter 21A, Section 13 of the Massachusetts General Laws requires the Commissioner of the DEP to adopt, and from time to time amend, regulations to be known as the State Environmental Code. More specifically, this code "shall deal with matters affecting the environment and the well being of the public of the Commonwealth." Section 13 also states that "local Boards of Health shall enforce said code in the same manner in which local health rules and regulations are enforced."

Pursuant to MGL Chapter 21A, Section 13, the DEP has promulgated **310 CMR 15.00, "Minimum Requirements for the Subsurface Disposal of Sanitary Sewage, State Environmental Code, Title 5."** These regulations provide minimum standards for the location, design, construction, and operation of subsurface sanitary sewage disposal systems that discharge less than 10,000 gallons per day. The improper location, construction, or maintenance of a subsurface disposal system is of concern because it may adversely affect the quality of the water obtained from a nearby private water system.

It should be noted that the standards presented in the current version of Title 5 were developed primarily to protect public health from pathogenic viruses and bacteria. Local hydrogeologic conditions may require more stringent regulations. Pursuant to the Massachusetts General Laws **Chapter 111, Section 31,** local Boards of Health have the authority to adopt reasonable regulations as long as they are not less stringent than Title 5. On the other hand, a variance may be granted if (1) site specific conditions indicate that adequate protection can be provided without complying with the standards required by Title 5, and (2) Title 5 requirements would be a manifest injustice. Part II of Title 5 includes procedures for obtaining a variance. Generally, the local Board of Health may grant a variance but there are also specific requirements for which Title 5 expressly states that only the DEP (Waste Water Management Program) may grant variances. All variances granted by the local Board of Health must be sent to the DEP for review. The DEP has the authority to overrule the Board of Health's decision.

Chapter 131, Section 40 of the Massachusetts General Laws provides the DEP with the authority to promulgate regulations to protect wetland areas and confers upon the local Conservation Commission the responsibility for administering the law. Among the seven statutory interests are "public or private water supply" and "groundwater supply." Pursuant to MGL Chapter 131, Section 40, the DEP has promulgated **310 CMR 10.00, "Wetlands Protection."** In accordance with MGL Chapter 131, Section 40 and 310 CMR 10.00, any person proposing construction or alteration of the land within 100 feet of a wetland or within the 100-year floodplain of any river or stream must apply to the local Conservation Commission for a Determination of Applicability. The Commission evaluates the impact prior to issuing a permit or denial and must ensure that "the capacity of an area to prevent pollution of groundwater shall not be adversely affected." The Commission's decision may be appealed to the Department of Environmental Protection.

The **"Drinking Water Regulations," 310 CMR 22.00,** promulgated by the DEP, pertain specifically to public water systems. However, they include water quality standards which can be used as guidelines for interpreting the results of analyses performed on water samples obtained from private water systems.

Department of Agricultural Resources, Pesticide Board

Pursuant to the Massachusetts General Laws **Chapter 132B**, the Pesticide Board promulgated **333 CMR 11.00, "Rights of Way Management**." These regulations include procedures and requirements for marking and recording the location of private drinking water supplies which are within one hundred feet of a right-of-way. For private drinking water supplies that are marked and recorded in accordance with these regulations, no herbicide shall be applied within fifty feet of the supply, and no herbicide shall be applied between fifty feet and one hundred feet of the supply unless a minimum of twenty-four months shall elapse between applications, and herbicides shall be applied selectively by low pressure foliar techniques or stem application. Uniform standard signs have been produced and are currently available at the Department of Agricultural Resources.

Department of Public Health

Chapter 111, Section 127A of the Massachusetts General Laws states that the Department of Public Health (DPH) "shall adopt, and may from time to time amend, public health regulations to be known as the State Sanitary Code." This code "shall deal with matters affecting the health and well-being of the public including, standards of fitness for human habitation."

MUNICIPAL JURISDICTION

Pursuant to the Massachusetts General Laws **Chapter 40, section 54**, which governs the powers and duties of cities and towns, "**no building permit shall be issued for the construction of a building which would necessitate the use of water therein, unless a supply of water is available"** from either a public or a private water system.

In accordance with the Massachusetts General Laws **Chapter 111, Sections 122 and 122A,** if the available supply of drinking water in any place of habitation is so unsafe or inadequate as to constitute a nuisance, the local Board of Health may issue a written order requiring the owner to discontinue use of the water supply, or, at his option, to provide a safe and adequate supply of drinking water.

Chapter 40, Section 21 of the Massachusetts General Laws grants municipalities the authority to adopt ordinances and bylaws which may, for example, require land owners to properly maintain their private water supply system and properly decommission abandoned water supply systems located on their property.

Chapter 83, Section 3 of the Massachusetts General Laws grants local Boards of Health the authority to require any landowner whose land abuts a public sewer system to hook into the public system at his or her own expense. Thus, the Board of Health can protect underground water supplies when a septic system threatens groundwater quality. Furthermore, the Board of Health's decision on such matters cannot be overridden by the Sewer Commissioners •

Chapter 111, Section 31 of the Massachusetts General Laws grants local Boards of Health broad authority to "make reasonable health regulations." Boards of Health are encouraged to adopt locally appropriate private well regulations which take into consideration local geology, land uses, and zoning regulations. It is the duty of local Boards of Health to monitor local conditions and create necessary regulations which address those conditions in order to protect public health. The following are examples of reasonable regulations that local Boards of Health may adopt under MGL Chapter 111, Section 31:

(1) setback distances required by Title 5 may be increased

(2) standards may be adopted governing the construction, alteration, maintenance, and decommissioning of private water supply systems

(3) periodic inspection and pumping of each septic system in the community may be required

(4) periodic testing of water from private water systems may be required

Adoption of health regulations by a Board of Health pursuant to MGL Chapter 111, Section 31, requires a majority vote of the Board and publication in a local newspaper. Pursuant to the Massachusetts General Laws, Chapter 21A, Section 8, regulations adopted under Chapter 111, Section 31, must be filed with the Department of Environmental Protection.

WATER SUPPLY SOURCES AND TYPES OF DOMESTIC WATER SUPPLY SYSTEMS

This section consists of the following subsections:

- Types of Domestic Water Supply Systems
- Groundwater Supplies
- Surface Water Supplies

TYPES OF DOMESTIC WATER SUPPLY SYSTEMS

Domestic water supplies in Massachusetts are supplied by either groundwater or surface water. Groundwater supplies most often utilize water wells to draw water from unconsolidated (sand and gravel) deposits or from fractured bedrock. Springs, also supplied by groundwater, serve a small percentage of the population and may utilize a cistern for storing water. Surface water bodies such as lakes, ponds, streams, rivers and brooks supply a relatively small population when compared with households utilizing wells.

GROUNDWATER SUPPLIES

This subsection consists of the following parts:

- Water Wells
- Springs

Water Wells

Subsurface geologic conditions throughout Massachusetts generally require one of two well construction techniques. A well drawing from a water bearing sand and gravel unit (overburden well) should be cased down to the most productive strata where an appropriately sized screen is installed. A well drawing water from bedrock fractures should be cased securely into the rock and the borehole in the rock is left open and unscreened and is used for storage.

There are several modifications of these two basic well types. Sandpoint wells, for example, consist of a screen coupled to a riser pipe which is pounded into a water bearing unit with tools that may be as simple as a sledge hammer. This type of well and installation technique is satisfactorily used in areas where the water table is close to the land surface and the ground being penetrated is sandy and devoid of cobbles, boulders and large gravel.

Dug wells, another modification of the basic overburden water well, are sometimes dug by hand but more often are constructed using a backhoe. These wells consist of large holes in the ground that extend below the water table and are lined with a large well screen, tile, or brick. Dug wells are generally constructed in areas where the water table is close to the land surface and where the geologic deposits are tight and compact, such as glacial till. Dug wells act as collection galleries or cisterns as groundwater seeps slowly into the collection area to the same level as the surrounding water table. Fluctuations, in the level of the water table may cause them to go dry and, unless they are adequately sealed to prevent infiltration of surface water, they are also vulnerable to contamination problems associated with the large annular space that typifies dug well construction.

The section entitled, "General Well Design and Construction" presents construction details for the aforementioned overburden wells and information pertaining to bedrock wells.

Springs

Springs emanating from rock or glacial till areas provide drinking water for a small percentage of the populace that depends on private sources. Frequently, larger transient populations stopping to fill water jugs at roadside springs require evaluating the source as though it were a public water supply. Springs are frequently connected and piped to concrete galleries that allow spillover to be piped elsewhere. Because springs may flow some distance as surface water and their collection systems are frequently open, they can easily become contaminated, and should be sampled regularly. Spring boxes or spring houses may add some sanitary protection to a spring. If constructed properly (Figure 1), they provide a sanitized discharge point and isolate the spring from contamination that could be introduced at the land surface.

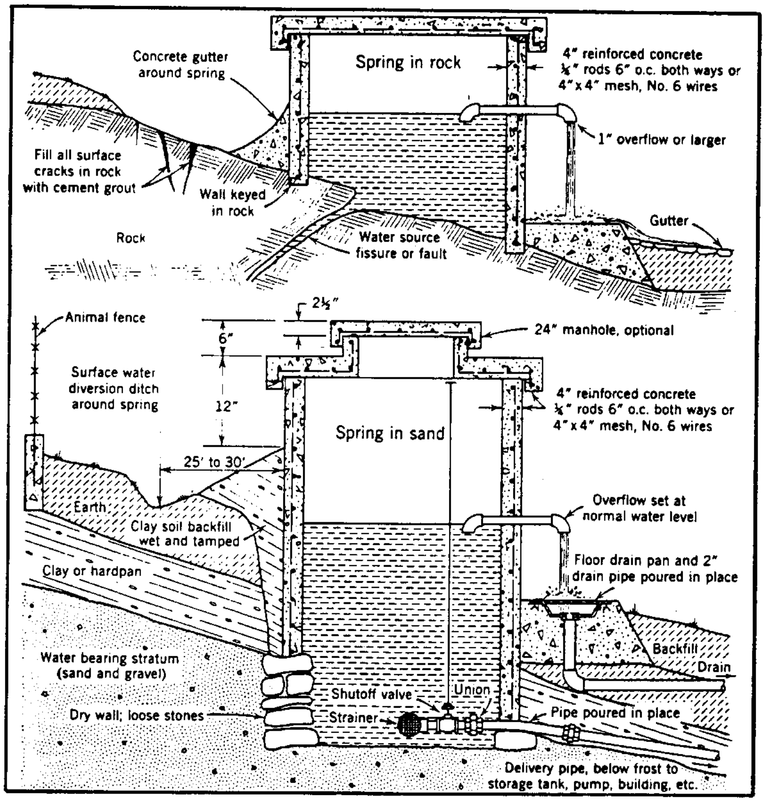

Figure 1: Properly Constructed Springs (Salvato, 1958)

SURFACE WATER SUPPLIES

Surface waters are rarely used for private drinking water supplies in Massachusetts. Because of their exposure to the air and a lack of filtering media, surface waters often experience water quality problems not associated with groundwater sources and frequently require some form of treatment in order to meet aesthetic and public health concerns. Algal blooms, bacterial contamination, turbidity, sedimentation and temperature fluctuations are some of the water quality problems associated with surface water supplies.

Surface waters are not recommended for use as a domestic drinking water supply. Homeowners using drinking water derived from private surface water sources should exercise caution and maintain rigorous and regular water quality sampling and testing practices.

PERMITS AND REPORTS

This section consists of the following subsections:

- Permits
- Reports

PERMITS

This subsection consists of the following parts.

- Required Registration of Well Diggers and Drillers
- Required Building Permit
- Recommended Permits

Required Registration of Well Diggers and Drillers

Chapter 21, Section 16 of the Massachusetts General Laws requires any person engaged in the business of digging or drilling wells within the Commonwealth to register annually with the Division of Water Supply Protection of the Department of Conservation and Recreation. In addition, MGL Chapter 21, Section II, authorizes the Division of Water Supply Protection to establish regulations necessary for the proper administration of the law cited above. The regulations developed by the Division of Water Supply Protection are contained in 313 CMR 3.00, "Water Well Diggers and Drillers Registration." These regulations (1) provide the criteria necessary for the registration of well diggers and drillers in the Commonwealth of Massachusetts, (2) establish the information that must be furnished as a prerequisite for registration, (3) establish the information that must be submitted to the Division of Water Supply Protection upon the completion of any well, and (4) set forth penalties, including revocation of registration, if a driller is found to be in noncompliance with state or town regulations.

Accordingly, any person in the business of digging or drilling who constructs, repairs, or alters a private well must be registered with the Division of Water Supply Protection at the time the work is performed. In addition, any person who decommissions (plugs) an abandoned well must have a valid Division of Water Supply Protection registration.

Required Building Permit

Pursuant to MGL Chapter 40, Section 54, which governs the powers and duties of cities and towns, "no building permit shall be issued for the construction of a building which would necessitate the use of water therein, unless a supply of water is available" from either a public or a private water system.

Recommended Permits

Requiring permits for activities related to private wells can provide information necessary for the protection of public health. In addition, local water supply resources can be properly evaluated and protected only when information pertaining to the use and quality of these resources is available. Chapter 111, Section 31 of the Massachusetts General Laws grants local Boards of Health broad authority to "make reasonable health regulations." Accordingly, various permit requirements may be established for activities related to private wells.

It is recommended that local Boards of Health establish, for example, requirements for the following:

(1) private well construction permit
(2) plumbing permit
(3) private well alteration permit
(4) renewable private well use permit
(5) permit for decommissioning (plugging) abandoned wells, test holes, and dry or inadequate borings

A private well construction permit allows the regulating agency to identify well sites that may require special water quality monitoring or may not be acceptable due to water quality problems that have occurred in the vicinity of the site. It is recommended that the application for a well construction permit be submitted by the property owner or his designated representative to the Board of Health on a form furnished by the Board. The application should include:

(1) the property owner's name and address
(2) the well driller's name and proof of valid state registration
(3) a plan with a specified scale, signed by a registered surveyor or engineer, showing the location of the proposed well in relation to existing or proposed above or below ground structures
(4) a description and location of visible prior and current land uses within two-hundred (200) feet of the proposed well location, which represent a potential source of contamination, including but not limited to the following:
    (a) existing and proposed structures
    (b) subsurface sewage disposal systems
    (c) subsurface fuel storage tanks
    (d) public ways
    (e) utility rights-of-way
    (f) any other potential sources of pollution
(5) proof that the owner of any property abutting the applicant's property has been notified of the applicant's intention to install a well
(6) a permit fee

A plumbing permit can ensure that only qualified persons connect a private well to the distribution system of the residence. A private well use permit allows the Board or Health to identify wells which may be threatened by contamination; can assist with the establishment of a local water quality monitoring program, and aids in identifying abandoned wells which should be plugged.

It should be the responsibility of the landowner, or the landowner's agent, to provide any and all permits that are required by the local Board of Health.

REPORTS

This subsection consists of the following parts.

- Well Completion Report Required by the Division of Water Supply Protection
- Recommended Pumping Test Report
- Recommended Water Quality Report
- Recommended Decommissioning Report

Well Completion Report Required bv the Division of Water Supply Protection

Requirements of 313 CMR 3.00 state, in part, that within thirty (30) days after completion of any well (productive or nonproductive), or after plugging of an abandoned well, a registered well driller shall submit to the Division of Water Supply Protection, with a copy to the local Board of Health, a report containing:

(1) the name and address of the owner of the well
(2) the geographic location of the well (this shall be given accurately to enable easy plotting on a U. S. Geological Survey Topographic (1:25,000 scale) Map)
(3) work performed (i.e., new installation, repair, abandonment)
(4) proposed use of well (if proposed use as public water supply other than municipal , describe public water supply classification under “other”)
(5) drilling method
(6) drilling log describing the material penetrated, including:
  (a) well depth
  (b) depth to refusal or bedrock
  (c) bedrock type
(7) site sketch
(8) date drilling completed
(9) casing type, size and length
(10) protective well seal
(11) well screen type, slot size, length, and depth at which bottom of well screen is set
(12) description of filter pack and grouting materials used
(13) method of plugging an abandoned well
(14) method used to test well yield including:
  (a) date and length of time (in hours and mins) well pumped
  (b) drawdown and recovery
  (c) well yield
(15) static water level
(16) pump description, depth and installer

Well Completion Report forms are available from the Division of Water Supply Protection. Any driller who files a false report is subject to revocation of registration.

Massachusetts Department of Environmental Management
Office of Water Resources

Well Completion Report

101628

TYPE OR PRINT ONLY

1. WELL LOCATION GPS (OPTIONAL) LATITUDE ________ LONGITUDE ________

Address at Well Location: ________ Property Owner: ________
Subdivision Name: ________ Mailing Address: ________
City/Town: ________ City/Town: ________
Assessors Map ________ Assessors Lot #: ________ NOTE: Assessors Map and Lot # mandatory if no street address available
Board of Health permit obtained: Yes ☐ Not Required ☐ Permit Number ________ Date Issued ________

2. WORK PERFORMED
☐ New Well ☐ Abandon
☐ Deepen ☐ Recondition
☐ Replace ☐ Other ________

3. PROPOSED USE
☐ Domestic ☐ Irrigation
☐ Monitoring ☐ Municipal
☐ Industrial ☐ Other ________

4. DRILLING METHOD
☐ Cable ☐ Auger
☐ Air Hammer ☐ Direct Push
☐ Mud Rotary ☐ Other ________

5. WELL LOG

From (ft)	To (ft)	WATER	Permeability High	Permeability Low	Clay	Silt	Sand	Gravel	Cobbles	Boulders	Other (Unconsolidated)	Rock Type (Consolidated)

6. SITE SKETCH (Use permanent landmarks with distances)

7. WELL CONSTRUCTION
Total Depth Drilled ________
Date Drilling Complete ________

8. CASING

From (ft)	To (ft)	Casing Type and Material	Size O.D. (in)	Well Seal Type

9. SCREEN

From (ft)	To (ft)	Slot Size	Screen Type and Material	Screen Diameter

10. FILTER PACK / GROUT / ABANDONMENT MATERIAL

From (ft)	To (ft)	Material Description	Purpose

11. ADDITIONAL WELL INFORMATION
Developed? ☐ Yes ☐ No
Fracture Enhancement? ☐ Yes ☐ No
Method ________
Disinfected? ☐ Yes ☐ No

12. WELL TEST DATA (PRODUCTION WELLS)

Date	Method	Yield (GPM)	Time Pumped (hrs & min)	Drawdown to (Ft. BGS)	Time (hrs & min)	Recovery to (ft. BGS)

13. STATIC WATER LEVEL (ALL WELLS)

Date Measured	Depth Below Ground Surface (FT)

14. PERMANENT PUMP (IF AVAILABLE)
Pump Description ________ Horsepower ________
Pump Intake Depth ________ (ft) Nominal Pump Capacity ________ (gpm)

15. NAME/ADDRESS OF PUMP INSTALLATION COMPANY

16. COMMENTS

17. WELL DRILLER'S STATEMENT This well was drilled and/or abandoned under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge.

Driller: ________ Supervising Driller Signature: ________ Registration #: ________
Firm: ________ Date: ________ Rig Permit #: ________

NOTE: Well Completion Reports must be filed by the registered well driller within 30 days of well completion.

DRILLER COPY

Figure2: Well Completion Report Required by the Division of Water Supply Protection. Completed in triplicate, the driller retains the first page and is required to submit the second and third pages to the local Board of Health and the Division of Water Supply Protection, respectively.

Recommended Pumping Test Report

All pumping test data should be recorded and included in a report that the contractor should submit to the well owner. If the well driller performs the pumping test, a copy of the pumping test report should be appended to the Well Completion Report that is submitted to the local Board of Health and the Division of Water Supply Protection.

The Pumping Test Report should include, but not be limited to, the following information:

(1) name and address of the well owner
(2) well location, referenced to at least two permanent structures or landmarks
(3) date the pumping test was performed
(4) depth at which the pump was set for the test
(5) location of the discharge line
(6) the static water level immediately before pumping commenced
(7) the discharge rate and, if applicable, the time the discharge rate changed
(8) pumping water levels and respective times after pumping commenced
(9) the maximum drawdown during the test
(10) the duration of the test, including both:
  a) the pumping time, and
  b) the recovery time during which measurements were taken
(11) recovery water levels and respective times after cessation of pumping
(12) reference point used for all measurements

Recommended Water Quality Report

It is recommended that the local Board of Health require the well owner to submit to the Board a Water Quality Report any time a private water supply is tested. Recommended sampling and testing requirements are discussed in the section entitled "Water Quality and Water Testing (page 60). The Water Quality Report should include:

(1) who performed the sampling (i.e., BOH member, BOH agent, lab personnel, well owner, well owner's agent)
(2) where in the system the sample was obtained (point-of-use or point-of-entry) and, if sampled at the point-of-use, whether or not the system was flushed prior to sampling
(3) type of water treatment used (chemical or special device), if applicable
(4) how long after sampling the sample was delivered to the laboratory
(5) a copy of the laboratory's test results

Results that indicate no contamination are as important as those that indicate water quality problems because these results provide background data in case of future contamination. A complete record of all testing results is also useful when designing local water quality testing programs.

<u>Recommended Decommissioning Report</u>

Within 30 days following the completion of the plugging procedure, the registered well driller who plugged the abandoned well, test hole, or dry or inadequate boring must submit a Well Completion Report to the Division of Water Supply Protection and should submit a Decommissioning Report to the owner of the property where the well, test hole, or boring is located. It is recommended that the local Board of Health require that the property owner file a copy of the Decommissioning Report with the appropriate Registry of Deeds or Land Court as part of the chain-of -title. Another copy of the Decommissioning Report should be submitted to the Board of Health. It is recommended that the copy submitted to the Board of Health include the Book and Page reference and the name of the Registry of Deeds where the report was filed or, in the case of registered land, the appropriate Land Court reference.

The following information should, <u>when available,</u> be included in the Decommissioning Report:

(1) name and address of the property owner
(2) name and address of the registered well driller who performed the plugging
(3) reason for abandonment
(4) location of the well, test hole, or boring referenced to at least two permanent structures or, when possible, location coordinates determined by a registered land surveyor or registered civil engineer
(5) all information known about the well, test hole, or boring including but not limited to:
  (a) depth
  (b) diameter
  (c) type of casing
(6) calculations made to determine the volume of the well, test hole, or boring
(7) static water level before plugging
(8) types of plugging material used, including mix specifications
(9) quantity of each type of plugging material used
(10) description of the plugging procedure including, but not limited to, notes regarding:
  (a) removal of pump and other obstructions
  (b) removal of screen
  (c) perforation or removal of casing
  (d) method(s) used to place plugging material (s)
(11) a copy of the original well driller's report, when available
(12) a copy of the abandonment permit, if a permit is required by the local Board of Health

WELL LOCATION

This section consists of the following subsections:

- General Considerations
- Relation to Property Lines and Buildings
- Relation to Gas Lines and Overhead
- Relation to Surface Water and Wetlands
- Requirements of the State Environmental Code, Title 5
- Additional Considerations

GENERAL CONSIDERATIONS

Any person intending to have a private well constructed should identify all potential sources of contamination which exist within 200 feet of the site. Where possible, a well should be located upgradient of all potential sources of contamination and should be as far removed from potential sources of contamination as the general layout of the premises and surroundings permit. Additionally, every well should be located so that it will be reasonably accessible with proper equipment for repair, maintenance, testing, and inspection.

The well should be completed in a water bearing formation that will produce the required quantity of water under normal operating conditions without adversely impacting adjacent wells. Water quantity considerations are discussed in the section entitled "Water Quantity (Pumping Test)" (page 47).

RELATION TO PROPERTY LINES AND BUILDINGS

Private water supply wells should be located at least ten feet from all property lines. The center line of a well should, if extended vertically, clear any projection from an adjacent structure by at least five feet.

RELATION TO GAS LINES AND OVERHEAD POWER LINES

A well should be located a minimum of 15 feet from a gas line or overhead electric distribution line and should be at least 25 feet from an electric transmission line which is in excess of 50 kV**.** When subsurface utilities are already in place. Dig Safe should be contacted at least three days before drilling begins.

RELATION TO ROADS AND RIGHTS-OF-WAY

All private water supply wells should be located at a minimum of 25 feet from the normal driving surface of any roadway or a minimum of 15 feet from the road right-of-way, whichever is greater. Additionally, it should be noted that the "Rights-of-Way Management" regulations (333 CMR 11.00) include procedures and requirements for marking and recording the location of private drinking water supplies which are within one hundred feet of any right-of-way. Private drinking water supplies that are marked and recorded in accordance with the aforementioned regulations are protected by restrictions on the use of herbicides for maintaining rights-of-way. Uniform standard signs for marking water supplies have been produced and are currently available from the Department of Agricultural Resources.

RELATION TO SURFACE WATER AND WETLANDS

Private water supply wells should be located at least 25 feet, laterally, from the normal high water mark of any lake, pond, river, stream, ditch, or slough. Additionally, it should be noted that land use within 100 feet of a wetland or within the 100-year floodplain of any river or stream is regulated under Chapter 131, Section 40, of the Massachusetts General Laws and 310 CMR 10.00, "Wetlands Protection." Prior to constructing a private water supply in these areas, approval must be obtained from the local Conservation Commission. Where possible, private water systems should be located in areas above the 100-year floodplain. When a well must be located in an area subject to flooding, special protection should be provided, as is discussed in the section entitled "Wellhead Completion" (page 59).

REQUIREMENTS OF THE STATE ENVIRONMENTAL CODE. TITLE 5

Pursuant to Chapter 21, Section 13, of the Massachusetts General Laws, the Department of Environmental Protection promulgated 310 CMR 15.00, "Minimum Requirements for the Subsurface Disposal of Sanitary Sewage, State Environmental Code, Title 5." These regulations provide minimum standards for the location, design, construction, and operation of subsurface sanitary sewage disposal systems that discharge less than 10,000 gallons per day.

It should be noted that the standards presented in the current version of Title 5 were developed primarily to protect public health against pathogenic viruses and bacteria. Local hydrogeologic conditions may require more stringent regulations. Boards of Health have the authority to strengthen Title 5 by implementing appropriate and reasonable local regulations.

Under Title 5, surface water supplies (reservoirs) or tributaries to reservoirs, including open and subsurface drains must be located a minimum of:

(1) 50 feet from a septic tank
(2) 100 feet from a leaching facility
(3) 100 feet from a privy

According to Title 5, these distances "shall be measured from the average of the mean annual flood elevation in inland areas and from mean high water in coastal areas." It should also be noted that for (2) and (3), above. Title 5 states that "100 feet is a minimum acceptable distance and no variance shall be granted for a lesser distance except with prior written approval of the Department of Environmental Protection”.

Title 5 also requires that a well or suction line or well be located a minimum of:

(1) 10 feet from a building sewer constructed of durable corrosion resistant material with watertight joints, or 50 feet from a building sewer constructed of any other type of pipe
(2) 50 feet from a septic tank
(3) 100 feet from a leaching field
(4) 100 feet from a privy

For (3) and (4) above, Title 5 notes that "100 feet is a minimum acceptable distance and no variance shall be granted for a lesser distance except with prior written approval of the Department of Environmental Protection."

In regard to pressurized water supply lines. Title 5 states that "it is suggested that the disposal facilities be installed at least 10 feet from and 18 inches below water supply lines. Wherever sewer lines must cross water supply lines, both pipes shall be constructed of class 150 pressure pipe and should be pressure tested to assure watertightness."

Part II of Title 5 includes procedures for obtaining a variance. Generally, the local Board of Health may grant a variance but there are also specific requirements for which Title 5 expressly states that only the Department of Environmental Protection (Waste Water Management Program) may grant variances. In order to grant a variance, however, it is important to have site specific hydrogeologic information submitted which documents that adequate protection can be provided without complying with the standards required by Title 5. All variances granted by the local Board of Health must be sent to the DEP for review. The DEP has the authority to overrule the Board of Health's decision.

ADDITIONAL CONSIDERATIONS

Several states have regulations pertaining to the location of a well in relation to a number of specified potential sources of contamination. The following examples indicate the range of minimum lateral distances required: (1) petroleum storage tanks; 20 feet to 50 feet, (2) stables, barnyards, feedlots, manure piles, and manure storage tanks; 50 feet to 100 feet. These distances may be used as guidance for locating a well but it is not recommended that they be adopted as regulations because the potential hazard to a well depends on site specific hydrogeology. For example, consideration should be given to the direction of ground-water flow and the location of any groundwater discharge to a surface water body. Where possible, wells should be located upgradient of potential sources of contamination. Wells should not be located between a potential source of contamination and an area where groundwater discharges to the land surface. Other considerations for locating a well include the permeability, transmissivity, and composition of the subsurface geologic materials. It should be kept in mind that contaminants can be transported great distances through fractured bedrock and groundwater flow in the overburden may not be in the same direction as in the bedrock.

GENERAL WELL DESIGN AND CONSTRUCTION

This section consists of the following subsections:

- General Considerations
- Well Design
- Cleaning and Disinfection of Drilling Equipment
- Drilling Fluids
- Temporary Cover

GENERAL CONSIDERATIONS

This subsection is a compilation of miscellaneous items that should be considered when designing and constructing a private water supply well.

All private water supply wells should be designed so that:

(1) the materials used for the permanent construction are durable in the specific hydrogeologic environment that occurs at the well site; and

(2) no unsealed openings will be left around the well that could conduct surface water or contaminated groundwater vertically to the intake portion of the well or transfer water from one formation to another.

In addition, permanent construction materials should not impart toxic substances, taste, odors, or bacterial contamination to the water in the well. It should also be noted that lead packers should not be used in the construction of any water supply wells.

The driller should operate all equipment according to generally accepted standards in the industry and should take appropriate precautions to prevent damage, injury or other loss to persons and property at the drilling site.

A well under construction should be protected so that surface wash is diverted away from the construction area and contaminants do not enter the well through the opening or by seepage through the ground surface, in addition, workers employed at the construction site should exercise caution in the disposal of wastes and in handling construction materials so as to avoid contamination of the well and the aquifer. The contractor should also take reasonable precautions to prevent either tampering with the well or the entrance of foreign material into the well during overnight shutdowns and other times when the contractor is away from the site.

During drilling, it is recommended that formation samples be taken at each change in formation. The sample depth and composition should be recorded in the driller's log. Well yield should be measured and recorded at least every 50 feet during drilling in order to prevent drilling to excessive depths.

All water used for drilling, development, or rehabilitation should be obtained from a source which will not result in contamination of the well or the water bearing zones penetrated by the well. Water should be conveyed in clean sanitary containers or water lines and should be chlorinated to an initial concentration between 50 mg/l and 100 mg/l and a free-chlorine residual of 10 mg/l should be maintained. Water from water bodies such as wetlands, swamps, and ponds should not be used.

All wells, including those that have been hydrofractured, should be developed in order to remove fine materials introduced into the pore spaces or fractures during construction. One or more of the following methods should be used for development: overpumping, backwashing, surging, jetting, air-lift pumping.

The completed well should be sufficiently straight so that there will be no interference with installation, alignment, operation or future removal of the permanent well pump.

Any work involving the connection of the private well to the distribution system of the residence must conform to the local plumbing code. All electrical connections between the well and the pump controls and all piping between the well and the storage and/or pressure tank in the house should be made by a pump installer or registered well driller. It is recommended that the pump installer be certified by the National Water Well Association for the installation of domestic pumps (1 to 3 hp).

WELL DESIGN

This subsection consists of the following parts:

- Drilled Wells
- Nonflowing Artesian Wells
- Sandpoint Wells
- Dug Wells

Drilled Wells

Several drilling methods are used for constructing private water supply wells. The efficiency of each drilling method depends to a great extent on the type of geologic formation being drilled. Other factors that affect the efficiency of a particular drilling method include the experience of the driller, the presence of geologic anomalies, and the hydraulic head of the aquifer or aquifers penetrated.

The specific design of a well depends on the subsurface geology at the well site and the drilling method used. Table I provides an example of some of the requirements for drilled water supply wells used by the State of Wisconsin (1985) and recommended by the U.S. Department of Health, Education, and Welfare (1965).

Nonflowing Artesian Wells

The following methods of construction (Figure 3) are recommended for wells completed in nonflowing artesian aquifers:

(1) Extend an oversized drillhole into but not through the confining layer, being sure that no water flows from the artesian zone into the drillhole

(2) Install an unperforated, watertight protective casing with the drive shoe

(3) Seal the annular space between the casing and the drillhole with neat cement grout or sand cement grout applied from the bottom of the drillhole upward to a depth which will adequately prevent subsurface leakage from the artesian zone

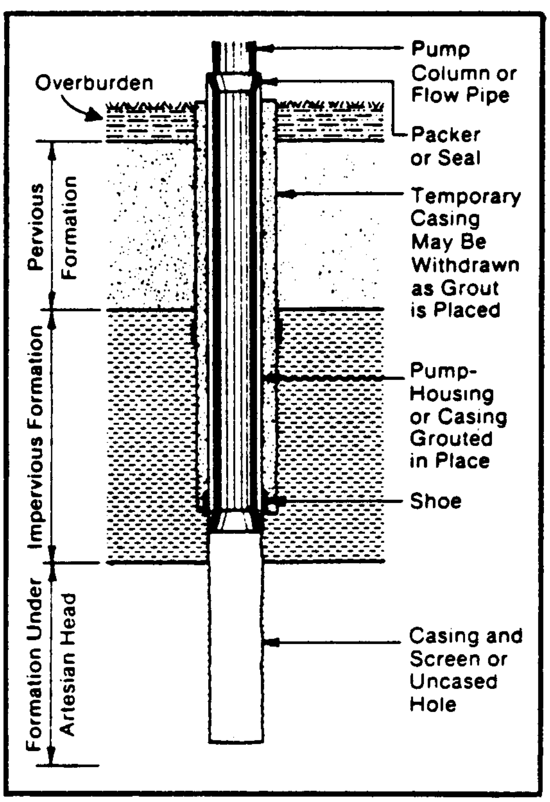

Figure 3: Appropriate Constuction for a Nonflowing Artesian Well (AWWA, 1984)

WATER-BEARING FORMATION (AQUIFER)	OVERBURDEN	OVERSIZED UPPER DRILLHOLE		LOWER DRILLHOLE DIAMETER		WELL SCREEN DIAMETER	MINIMUM CASING DEPTH	LINER DIAMETER (WHEN REQUIRED)	GENERAL CONSTRUCTION REQUIREMENTS
		MINIMUM DIAMETER	MINIMUM DEPTH	CASED PORTION	UNCASED PORTION				
Sand and/or gravel	Unconsolidated caving material; mainly sand or sand and gravel	Casing diameter plus 2 inches with rotary drilling Not required with cable tool drilling but shall be casing diameter plus 4 inches if constructed	To depth of casing setting with rotary drilling Not required with cable tool drilling but shall be to the depth of casing setting if constructed	Minimum 2 inches 4 inches or more preferred	Does not apply	Minimum 2 inches	20 feet or 5 feet below the pumping level,[1] whichever is greater	Minimum 2 inches; maximum 2 inches less than the lower drillhole diameter	<u>For flowing artesian wells</u>, the annular space between the soil and rock, and the well casing shall be tightly sealed with cement grout from within 5 feet of the top of the aquifer to the ground surface, according to good construction practice. <u>Minimum protective casing depths</u> listed are inadequate and shall be increased in areas where well histories indicate contamination, at greater depths. <u>Well screen diameters</u> listed shall also be applicable to perforated casing. Well points commonly designated in the trade as 1 1/4 inch shall be considered as being 2 inch well screens. <u>Well screen installation</u> shall be done in such a manner that removal or replacement can be accomplished without adversely affecting the watertight construction of the well. <u>Welded joints</u> shall be used instead of couplings when assembling well pipe which is only 2 inches smaller in diameter than the drillhole. <u>Protective liner pipe</u> shall be assembled with welded joints and sealed in place with cement grout applied in approved manner <u>Upper enlarged drillholes</u>, when not required with cable tool drilling, are sometimes constructed to facilitate the use of longer lengths of pipe. <u>With cable tool drilling</u>, the oversized upper drillhole, when constructed, shall be kept open with temporary casing, when necessary, and shall be kept at least one-third filled with clay slurry while driving the permanent well casing. After the casing is in the permanent position, the annular space shall be filled with clay slurry or cement grout applied in an approved manner. <u>With rotary drilling</u>, the oversized upper drillhole shall be maintained at full diameter with drilling mud or with temporary well casing. After the casing is in the permanent position, the annular space shall be filled with drilling mud or cement grout, except that only cement grout shall be used when the oversized upper drillhole is constructed more than 2 feet into firm rock. <u>Air rotary drilling is required</u> when the protective well casing placed in an upper enlarged drillhole is only 2 inches larger in diameter than the inner well casing.
Sand and/or gravel	Clay, hardpan, silt, or similar material with or without sand and/or gravel layers	Casing diameter plus 2 inches with rotary drilling Casing diameter plus 4 inches with cable tool drilling	20 feet	Minimum 2 inches 4 inches or more preferred	Does not apply	Minimum 2 inches	5 feet below the pumping level[1]	Minimum 2 inches; maximum 2 inches less than the lower drillhole diameter	
Sandstone	Any material to a depth of less than 25 feet	Casing diameter plus 2 inches with rotary drilling Casing diameter plus 4 inches with cable tool drilling	10 feet into firm sandstone or to a depth of 30 feet, whichever is greater	Minimum 6 inches	Does not apply	Minimum 2 inches, if required to permit pumping sand-free water from partially cemented sandstone	30 feet; more if required to firmly seat the casing into the sandstone	Minimum 2 inches; maximum 2 inches less than the lower drillhole diameter	
Sandstone	Unconsolidated caving material; mainly sand or sand and gravel to a depth of 25 feet or more	Casing diameter plus 2 inches with rotary drilling Not required with cable tool drilling but shall be casing diameter plus 4 inches if constructed	To firm sandstone with rotary drilling Not required with cable tool drilling but shall be at least 20 feet if constructed	Minimum 4 inches	4 inches with cable tool drilling Does not apply with rotary drilling	Minimum 2 inches, if required to permit pumping sand-free water from partially cemented sandstone	10 feet into firm sandstone; more if required to firmly seat the casing into the sandstone	Minimum 2 inches; maximum 2 inches less than the lower drillhole diameter	
Sandstone	Clay, hardpan, silt, or similar material with or without sand and/or gravel layers to a depth of 25 feet or more	Casing diameter plus 2 inches with rotary drilling Casing diameter plus 4 inches with cable tool drilling	To firm sandstone with rotary drilling 20 feet with cable tool drilling	Minimum 4 inches	4 inches with cable tool drilling Does not apply with rotary drilling	Minimum 2 inches, if required to permit pumping sand-free water from partially cemented sandstone	10 feet into firm sandstone; more if required to firmly seat the casing into the sandstone	Minimum 2 inches; maximum 2 inches less than the lower drillhole diameter	
Sandstone	Limestone or dolomite with or without overlying unconsolidated material to a depth of 25 feet or more	Casing diameter plus 2 inches with rotary drilling Casing diameter plus 4 inches with cable tool drilling	10 feet into firm sandstone or to a depth of 40 feet, whichever is greater	Minimum 6 inches	Does not apply	Minimum 2 inches, if required to permit pumping sand-free water from partially cemented sandstone	40 feet; more if required to firmly seat the casing into the sandstone	Minimum 4 inches; maximum 2 inches less than the lower drillhole diameter	
Fractured or shattered igneous or metamorphic rock such as granite, trap rock, or quartzite OR Creviced, shattered, or fractured limestone or dolomite[2]	Any material to a depth of less than 40 feet; No landfills, dumps, or quarries within a half-mile radius of the well site	Casing diameter plus 2 inches with rotary drilling Casing diameter plus 4 inches with cable tool drilling	40 feet	Minimum 6 inches	Does not apply	Does not apply	40 feet; more if required to firmly seat the casing into the rock	Minimum 4 inches; maximum 2 inches less than the lower drillhole diameter	
Fractured or shattered igneous or metamorphic rock such as granite, trap rock, or quartzite OR Creviced, shattered, or fractured limestone or dolomite[2]	Unconsolidated caving material; mainly sand or sand and gravel to a depth of 40 feet or more; No landfills, dumps, or quarries within a half-mile radius of the well site	Casing diameter plus 2 inches with rotary drilling Not required with cable tool drilling but shall be casing diameter plus 4 inches if constructed	To firm rock with rotary drilling Not required with cable tool drilling but shall be at least 20 feet if constructed	Minimum 6 inches	6 inches with cable tool drilling Does not apply with rotary drilling	Does not apply	10 feet into firm rock; more if required to firmly seat the casing into the rock	Minimum 4 inches; maximum 2 inches less than the lower drillhole diameter	
Fractured or shattered igneous or metamorphic rock such as granite, trap rock, or quartzite OR Creviced, shattered, or fractured limestone or dolomite[2]	Clay, hardpan, silt, or similar material with or without sand and/or gravel layers to a depth of 40 feet or more; No landfills, dumps, or quarries within a half-mile radius of the well site	Casing diameter plus 2 inches with rotary drilling Casing diameter plus 4 inches with cable tool drilling	To firm rock with rotary drilling 20 feet with cable tool drilling	Minimum 6 inches	6 inches with cable tool drilling Does not apply with rotary drilling	Does not apply	10 feet into firm rock; more if required to firmly seat the casing into the rock	Minimum 4 inches; maximum 2 inches less than the lower drillhole diameter	

*Requirements for the proper construction of wells vary with the character of the subsurface materials and provisions applicable under all circumstances cannot be fixed. As conditions warrant and with the approval of the regulating agency, the construction details of this Table may be adjusted.

[1] The term "pumping level" refers to the maximum drawdown occurring in the well during pumping, determined to the best knowledge of the water well contractor, accounting for usual seasonal fluctuations of the static water level and drawdown level.

[2] "Granite" and "trap rock" are general terms commonly used by well drillers to describe several different types of igneous and metamorphic rock. "Limestone" is a term commonly used by well drillers to describe both limestone and dolomite.

Adapted from Wisconsin Administrative Code NR 112, "Register," October 1985, No. 358 and from "Recommended State Legislation and Regulations," Dept. of Health, Education, and Welfare, Public Health Service, Washington, D.C., July 1965.

Table 1: Example of Requirements for Drilled Water Supplies*

(4) After the grout has set completely, extend the drillhole into the artesian zone being sure to packer that provides a watertight seal between the and outer casings

(5) Complete the well as recommended in the section entitled "Wellhead Completion" (page 47)

(6) If leakage occurs around the well casing or adjacent to the well, the well should be recompleted using additional casing, seals, and/or packers as necessary to completely eliminate leakage

Flowing artesian wells should be equipped with a shutoff valve and backflow preventer so that the flow of water can be stopped completely when the well is not in use. Watertight pump connections or a receiving reservoir set at an elevation corresponding to the artesian head may also be used. However, there should never be a direct connection between the discharge pipe and a receiving reservoir or any other potential source of contamination. The well owner should adjust the valves so that the quantity of water flowing from the well is adequate for ordinary use and no excess water is being wasted.

Sandpoint Wells

This part consists of the following subparts:

- General Considerations
- Installation

General Considerations

Sandpoint wells are installed only in unconsolidated formations which do not contain numerous cobbles and boulders. The maximum depth that can be attained with a sandpoint well is approximately 30 feet, if the well point is hand driven. If the well is jetted or if the well point is driven by a mechanical driver, however, a depth of 50 feet or more may be attained.

Sandpoint wells are commonly 1 1/4 to 2 inches in diameter. It is recommended that neither the well screen nor the well casing be less than 1 1/4 inch in diameter. In selecting casing, consideration should be given to the depth of the static water table, being sure to account for seasonal fluctuations. When the static water level is within about 15 feet of the land surface, the well can be pumped by suction lift and the casing diameter can be as little as 1 1/4 inch in diameter. However, if the static water level is deeper than about 15 feet, the well must be pumped by a jet pump or a cylinder pump.

All well casing should be unperforated and water tight. Under no circumstances should thermoplastic well casing be used for a driven well.

The depth of a sandpoint well should be sufficient to prevent breaking suction when pumping the well at a rate 50% greater than the capacity of the permanent pump. When possible, the casing should extend to a minimum depth of 20 feet or 10 feet below the pumping level, whichever is greater. The "pumping level" is the maximum drawdown occurring in the well during pumping, determined to the best knowledge of the water well contractor, accounting for usual seasonal fluctuations of the static water level and drawdown level.

Installation

The following procedure is recommended for installing hand driven sandpoint wells:

(1) Use a hand auger or a post hole digger and bore a hole which is:

(a) slightly larger in diameter than the wellpoint,
(b) vertical, and
(c) a minimum of 3 feet deep but as deep as possible.

(2) Using pipe-thread compound approved by the National Sanitation Foundation for water wells and couplings with recessed ends and tapered threads, either:

(a) connect the wellpoint to a 5-foot length of well casing or to a string of well casing; or
(b) connect the wellpoint to a coupling and place the wellpoint into a 5-foot length of oversized casing, attaching additional lengths of casing if desired.

Oversized casing protects the well screen and is used most often when driving deep wells.

(3) Place the wellpoint-casing assembly into the bored hole and backfill the hole.

(4) Attach an iron drive cap to the top of the casing.

(5) Drive the casing into the ground either by hand, using a weighted pipe similar to a fence post driver, or by using a mechanical driver. Add additional lengths of casing as needed until the desired depth has been attained.

(6) When oversized casing is used, expose the well screen at the predetermined depth either by driving it with an inner casing inserted through the oversized casing or by pulling back the oversized casing (Figure 4).

(7)Protect against freezing by means of a pitless adapter or an enclosing casing pipe.

Dug Wells

This part consists of the following subparts:

- General Considerations
- Construction of Standard Dug Wells
- Buried Slab Type Construction of Dug Wells

General Considerations

A dug well is a shallow well that is generally 20 to 35 feet deep and three to five feet in diameter. Dug wells can be excavated by hand but, due to federal occupational-safety laws, are more often excavated using a backhoe. Dug wells are generally less reliable than drilled wells and should be constructed only where hydrogeologic conditions preclude the construction of a satisfactory drilled well.

Although the relatively large diameter of a dug well provides a large water storage capacity, these wells often go dry when the water table drops during periods of drought. Additionally, since

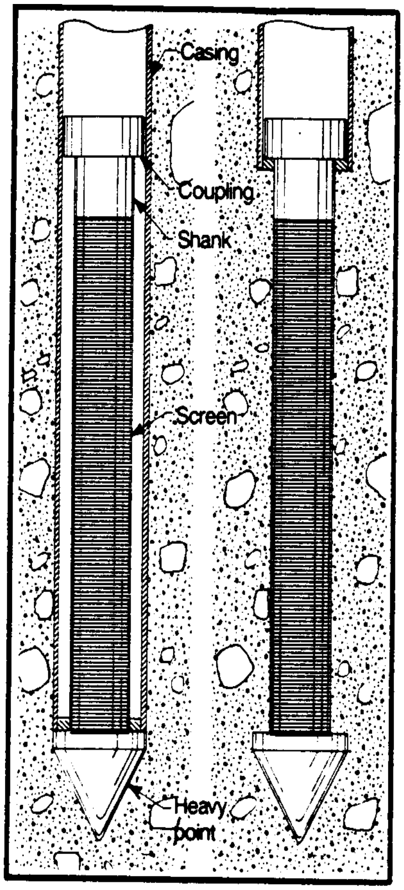

Figure 4: Sandpoint Installed with Protective Oversized Casing. During Driving , the casing pushed a special heavy duty drive point downward while the casing protects the screened portion of the wellpoint. The screen is exposed at the predetermined depth either by driving it with an inner casing inserted through the oversized casing or pulling back the oversized casing (Driscoll, 1986).

it is more difficult to dig below the water table, it is recommended that construction of a dug well take place during the months of August through October when the elevation of the water table tends to be at its annual low.

Due to the relatively large diameter of a dug well, concrete casing, also called curbing, is used instead of steel casing. When concrete is used, it consists of either precast concrete pipe or it is poured-in-place. The wall thickness of precast concrete pipe should be a minimum of three inches thick and poured-in-place concrete should have a wall thickness equal to at least six inches. Recommended specifications for concrete casing are discussed in the section entitled "Well Casing" (page 33).

The casing of a dug well should be watertight to the depth of the production aquifer or to a depth of 20 feet below the preexisting ground surface, whichever is greater. The upper terminus of the well casing should extend 12 inches above the pre-existing ground surface or two feet above the highest recorded flood, whichever is greater. All above-grade and below-grade connections should be watertight.

When precast concrete pipe is used to case a dug well, the excavation should be at least four inches larger than the outside diameter of the casing. The annular space between the face of the excavation and the casing should be sealed with neat cement grout or sand cement grout to a depth below the local frost line.

The intake portion of a dug well below the watertight casing should consist of perforated casing or a loosely laid wall of stone, concrete block, or brick. It must be of adequate strength to withstand any external pressure to which it may be subjected and must be seated firmly enough to prevent settling.

Dug wells are constructed using either a standard type design or a buried slab design. Specifics pertaining to these two types of design are discussed below.

Construction of Standard Dug Wells

The design and recommended construction specifications for standard dug wells are illustrated in Figure 5. When standard construction is used, the well should be provided with a cover made of reinforced concrete that is at least four inches thick. The cover should rest on and overlap the outer edge of the well casing by at least two inches. The cover should be constructed without joints. Adequately sized pipe sleeve required to accommodate the type of pump and pump piping proposed for the well should be cast in place when the cover is fabricated. The top of the cover should be sloped so that water drains away from the sleeve.

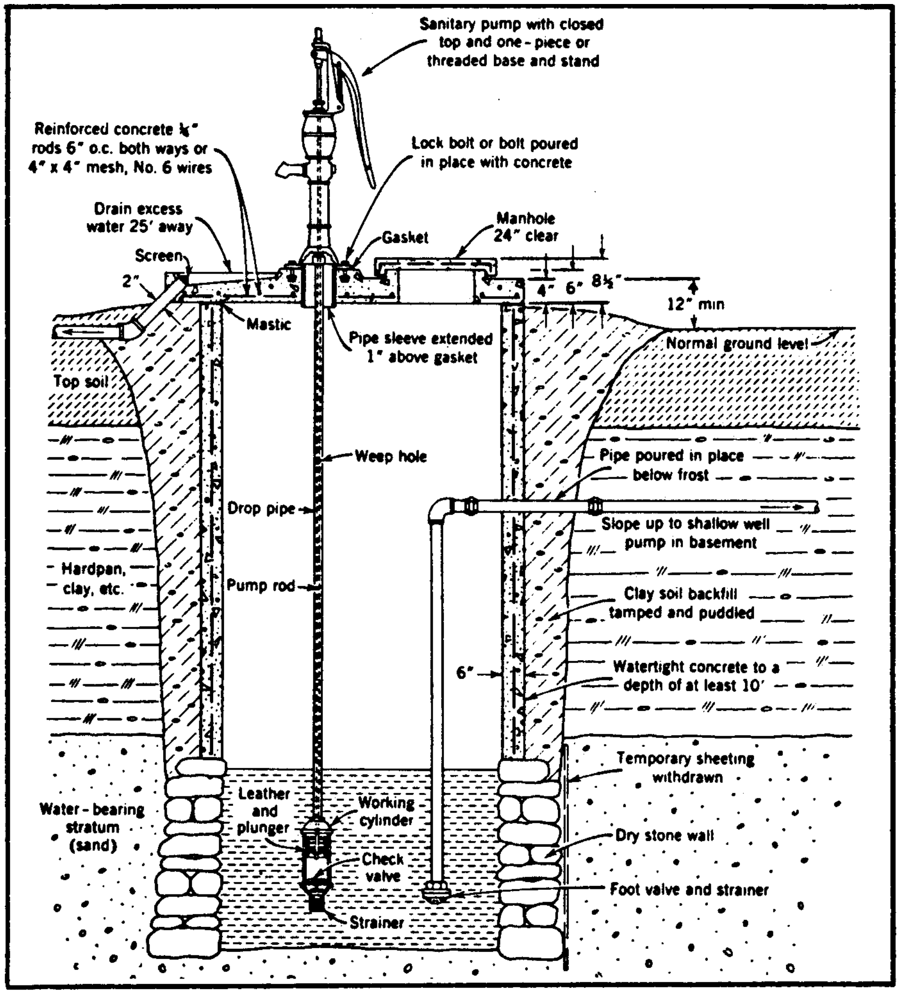

Figure 5: Construction Details a for Standard Dug Well (Salvato, 1958).

A manhole, if installed, should be provided with a curb which extends at least two inches above the top of the cover and is cast in place when the cover is fabricated. The manhole should be equipped with an overlapping cover, the sides of which extend downward around the curb at least one and one-half inches. The joint between the curbing and the cover of the manhole should be made watertight with a plastic sealing compound and the manhole cover should be locked or bolted in place

Buried Slab Type Construction of Dug Wells

Buried slab construction of a dug well (Figure 6) utilizes a steel reinforced concrete slab which is placed over and grouted to the lower portion of the well casing. The slab, which permits the use of casing with a substantially smaller diameter for the upper portion of the well, should be at least three inches thick and, when possible, should be placed at a depth equal to or greater than 20 ft. below the preexisting ground surface. The upper well casing should be a minimum of four inches in diameter and should be either firmly imbedded in the, slab or connected to a pipe cast in the slab. The seal between the upper well casing and the slab should be watertight and the annular space between the casing and the excavation should be grouted with neat cement grout or sand cement grout.

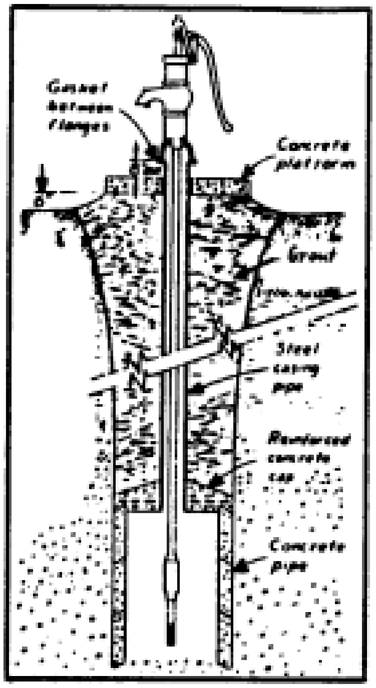

Figure 6: Dug Well Constructed with a Buried Slab

If the pump is to be installed over the well, a concrete platform should be provided. The platform should be equipped with an adequately sized cast-in-place pipe sleeve and the top of the platform should be sloped away from the sleeve in all directions.

CLEANING AND DISINFECTION OF DRILLING EQUIPMENT

In order to prevent the transfer of microbiological and chemical contaminants from previous drilling operations to uncontaminated groundwater, all drilling equipment, including pumps and down hole tools, should be cleaned and disinfected prior to drilling any new well or test hole. Disinfection of drilling equipment may be accomplished with a solution having a chlorine concentration equal to 100 mg/l. Other solutions used to decontaminate drilling equipment include trisodium phosphate, sodium carbonate, and sodium bicarbonate. A 10 percent aqueous solution of trisodium phosphate is good as a rinsing solution or detergent. A 10-20 percent aqueous solution of sodium carbonate is effective for cleaning inorganic acids from equipment. Sodium bicarbonate in a 5-15 percent aqueous solution can effectively clean both acids and bases from drilling equipment,

DRILLING FLUIDS

Drilling fluids are used with rotary drilling to:

(1) lift the cuttings from the bottom of the hole and carry them to a settling pit
(2) stabilize the borehole wall to prevent caving
(3) lubricate the bit, bearings, mud pump, and drill pipe
(4) control fluid loss by sealing the borehole wall
(5) facilitate the removal of cuttings into a settling pit

Drilling fluids used in the construction of water wells are either water or air based. The major types of water based drilling fluids consist of:

(1) clean, fresh water,
(2) water with clay additives,
(3) water with polymeric additives, or
(4) water with clay and polymeric additives.

The primary types of air based drilling fluids consist of:

(1) dry air,
(2) mist: droplets of water entrained in the airstream,
(3) foam:air bubbles surrounded by a film of water containing a foam-stabilizing surfactant (soap), or
(4) stiff foam: foam containing film-strengthening materials such as polymers and bentonite.

As indicated above, the primary drilling fluid additives are clays, polymers, and surfactants. Other additives which may be used include flocculants, dispersants (thinning agents), weighting materials, corrosion inhibitors, filtrate reducers, nontoxic lubricants, preservatives, lost-circulation materials, and bacteriacides.

The specific composition of the drilling fluid used depends primarily on the type of subsurface materials expected and the drilling equipment available. Availability of water at the drilling site and the experience of the drilling crew are also factors that affect drilling fluid selection. In general, water based drilling fluids with clay or polymeric additives are typically used for drilling unconsolidated formations while air based fluids are used for drilling well-consolidated or semiconsolidated rocks and sediment.

Regardless of the specific composition, all drilling fluids must be nontoxic. Drilling fluid additives should be stored in clean containers and should be free of material that may adversely affect the well, the aquifer, or the quality of the water to be pumped from the well. In addition, surfactants should be biodegradable. Although biodegradable organic polymers, such as guar gum, are commonly used as drilling fluid additives, it should be noted that their use has resulted in persistent microbiological contamination of groundwater supplies. Consequently, the use of biodegradable organic polymers should, when possible, be avoided.

It is recommended that all water used to mix a drilling fluid, as well as any makeup water added, be chlorinated. Depending on the particular additives used for the drilling fluid, the mix water should be chlorinated to a concentration between 50 mg/l and 100 mg/l. The latter concentration is recommended, for example, when organic biodegradable polymers are used in the drilling fluid. In addition, a free-chlorine residual of approximately 10 mg/l should be maintained in the fluid during drilling. This concentration may be easily determined with chlorine paper and should be checked periodically. Chlorination is important because it retards the growth of bacteria introduced into the well during drilling procedures.

It should also be noted that mix water should never be taken from wetlands, swamps, small lakes, or other similar surface waters because these water supplies often contain both pathogenic bacteria and iron bacteria. Iron bacteria are of concern because their growth in a well can substantially reduce the well yield and can degrade the quality of the water obtained from the well.

TEMPORARY COVER

When there is an interruption in work during construction or alteration of a well due to such factors as overnight shutdown, inclement weather, time required for the setting of sealing materials, testing, or a delay prior to installation of pumping equipment, the contractor should protect the well in such a manner as to effectively prevent tampering with the well or the entrance of foreign matter into it.

During interruptions of one week or longer, a semi-permanent watertight cover should be installed. For a well cased with steel, the semi-permanent cover should consist of a steel or cast iron cap, of at least three-sixteenths of an inch in thickness, tack welded to the top of the casing.

WELL CASING

This section consists of the following subsections:

- General Considerations
- Steel Water Well Casing
- Thermoplastic Water Well Casing
- Concrete Water Well Casing

GENERAL CONSIDERATIONS

Well casing, also called riser pipe, serves both as a housing for the pumping equipment and as a vertical conduit for the water pumped from the aquifer. Although the well casing generally extends from the intake portion of the well upward to the land surface, the lower portion of a drillhole may be left uncased when the well is completed in competent bedrock.

Private water supply wells should be constructed using steel, thermoplastic, or concrete well casing. The casing should be of adequate strength and durability to withstand anticipated formation and hydrostatic pressures; the forces imposed on it during installation; and the corrosive effects of the local hydrogeologic environment. The casing material used depends on the drilling method, the depth and diameter of the well, the character of the subsurface materials, and local groundwater quality. Thermoplastic casing, for example, is resistant to corrosive groundwater and acid treatment but it is not as strong as steel casing. Steel casing, on the other hand, should always be used when the casing is driven with a cable tool drilling rig or when the casing is installed in an open drillhole in which formation materials may suddenly collapse against the casing.

All casing used in the construction of private water supply wells should be free of pits, breaks, gouges, deep scratches, and other defects. If previously used casing is installed, it should not only be free of defects, as mentioned above, but should also have been used only in a water well test hole, or a dry or inadequate boring. Additionally, the casing should have been salvaged within 30 days of the original installation and should be decontaminated and disinfected prior to installation.

The diameter of the well casing must provide enough clearance for proper installation and operation of the well pump.

Installation of water well casing should be done in a manner that does not alter the shape, size, or strength of the casing and does not damage any of the joints connecting sections of the casing. Upon completion of the installation procedure, the entire length of the casing above the intake should be water tight.

STEEL WATER WELL CASING

This subsection consists of the following parts:

- Materials Standards
- Marking of Steel Water Well Casing
- Methods of Joining Steel Casing
- Installation of Steel Casing

Materials Standards

Due to the great variety of tubular steel products available, there are a number of different standards for materials considered acceptable for use as water well casing. All steel casing used in the construction of private water supply wells should consist of schedule 40 pipe that complies with one of the materials standards approved by the American Water Works Association (Table 2). In all cases, the wall thickness should be sufficient to withstand hydraulic loading if the casing is pumped dry and should have a collapse strength greater than one pound per square inch for every 2.31 feet of depth beneath the top of the aquifer (Driscoll, 1986).

Marking of Steel Water Well Casing

Each length of casing shall be legibly marked in accordance with the ASTM, API, or AWWA marking specifications noted in the most recent revision of the applicable standard showing, where respectively required:

(1) the name or trademark of the manufacturer or processor
(2) ASTM, API, or AWWA marking or monogram
(3) standard
(4) size in inches
(5) weight in pounds per foot
(6) whether seamless or welded and, if welded, type of weld
(7) grade
(8) length, in feet and tenths of feet

Methods of Joining Steel Casing

Segments of steel casing should be coupled by using threaded or welded joints. Recessed or reamed and drifted couplings should be used on threaded casing and no threads should be left exposed once the joint is completed. Generally, threaded joints are not used for casing that is larger than six inches in diameter. Welded casing joints should conform to the most recent revision of AWWA C206, "Standard for Field Welding of Steel Water Pipe." The weld should be at least as thick as the wall thickness of the well casing and should be fully penetrating. A fully penetrating weld means that, after the casing ends have been beveled at approximately 35 degrees, the entire beveled and flat area is filled with weld bead by making several passes around the casing. Welding must be done carefully in order to prevent burn-through on the first pass. If burn-through occurs, the slag deposited on the inside of the casing may impede the movement of tools within the casing or interfere with screen installation. When completed, a welded casing joint should have a tensile strength equal to or greater than that of the casing.

THERMOPLASTIC WATER WELL CASING

This subsection consists of the following parts:

- Materials and Materials Standards
- Marking of Thermoplastic Water Well Casing and Couplings
- Storage and Inspection of Thermoplastic Materials
- Methods of Joining Thermoplastic Casing
- Installation of Thermoplastic Casing

TABLE 2 MATERIALS STANDARDS FOR STEEL WATER WELL CASINGS[1]

-

AGENCY AND STANDARD #	TITLE OF STANDARD
API[2] 5L	Specification for Line Pipe
API 5LS	Specification for Spiral-Weld Line Pipe
ASTM[3] A53	Specification for Pipe, Steel, Black and Hot-Dipped Zinc-Coated Welded and Seamless
ASTM A120	Specification for Pipe, Steel, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless, for Ordinary Uses
ASTM A139	Specification for Electric-Fusion (Arc) Welded Steel Pipe (NPS 4 and Over)
ASTM A211	Specification for Spiral-Welded Steel or Iron Pipe
ASTM A409	Specification for Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service
ASTM A589	Specification for Seamless and Welded Carbon Steel Water Well Pipe
ASTM A714	Specification for High-Strength Low-Alloy Welded and Seamless Steel Pipe
AWWA[4] C200	Standard for Steel Water Pipe, 6 Inches and Larger

[1] The most recent revision of each standard shall apply

[2] American Petroleum Institute, 2101 L Street, N.W., Washington, D.C. 20037

[3] American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

[4] American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235

Materials and Materials Standards

Three of the more common varieties of thermoplastic casing are: PVC (polyvinyl chloride), ABS (acrylonitrile butadiene styrene), and SR (styrene-rubber). The variety used most often in the construction of potable water supply wells is PVC. Casing made of ABS is generally used for nonpressure applications such as for drain pipe or low-head irrigation pipe.

Thermoplastic casing used in the construction of private water supply wells should be capable of withstanding pressures equal to or greater than 200 pounds per square inch and should conform to the most recent revision of ASTM Standard F480, "Specification for Thermoplastic Water Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR)." In addition, the casing and couplings should meet the requirements of the most recent revision of National Sanitation Foundation Standard Number 14, entitled "Plastics Piping System Components and Related Materials." Materials complying with Standard Number 14 can be recognized by the marking "NSF-WC."

Marking of Thermoplastic Water Well Casing and Couplings

Each length of casing shall be legibly marked in accordance with the ASTM marking specifications noted in the most recent revision of Standard F480 showing, where required:

(1) the nominal well casing pipe size
(2) the wording "well casing"
(3) type of material
(4) pressure rating (should be greater than or equal to 200 psi)
(5) standard dimension ratio
(6) impact classification
(7) ASTM standard designation "F480" (including year of issue of the standard with which the well casing pipe complies)
(8) "NSF-WC"
(9) designation of ASTM standard used for pressure testing
(10) "NSF-PW"
(11) name or trademark of the manufacturer
(12) the manufacturer's code for resin manufacture, lot number, and date of manufacturer

Each thermoplastic coupling shall be legibly marked in accordance with the ASTM marking specifications noted in the most recent revision of Standard F480 showing, where required:

(1) the nominal coupling size
(2) type of material
(3) ASTM standard designation "F480" (including year of issue of the standard with which the coupling complies)
(4) name of trademark of the manufacturer
(5) the NSF designation of approval for use in water well construction

Storage and Inspection of Thermoplastic Materials

Thermoplastic casing should be stored in such a manner as to prevent deformation, sagging, or bending. Storage of thermoplastic casing and couplings in direct sunlight should be avoided. Prior to use, the casing and couplings should be inspected for deformation, cuts, gouges, deep scratches, damaged ends, and other imperfections. Casing or couplings having any such defects should not be used for well construction.

Methods of Joining Thermoplastic Casing

Plastic casing should be joined by mechanical means only. Acceptable methods for joining thermoplastic casing include cam-locking and using threaded couplings. Cam-locking is a method in which a gasket is used to seal free casing segments. When threaded connections are made, the required thread lubricants and sealants used should be approved by the National Sanitation Foundation for use with casing for potable water supply wells. Solvent cement should not be used on the threads.

Installation of Thermoplastic Casing

Thermoplastic casing should be installed only in an oversized drillhole and should never be driven, pushed, or forced into a formation. When pulling back thermoplastic well casing to expose a well screen, the force applied should never exceed the casing weight.

A pitless adapter may be used provided it is installed below the regional frost line. A threaded coupling should be used to join thermoplastic casing to the pitless adapter and any lubricant used should be manufactured specifically for the type of thermoplastic casing installed in the well. Threaded joints should be tightened no more than one full turn using a strap wrench. The portion of the casing extending above the frost line when a pitless device is not installed should either consist of steel or should be capped with an oversized steel casing extending to a level above the top of the thermoplastic casing. When steel is used for the upper terminus of a well in which a pitless adapter is not installed, the steel casing should be attached to the thermoplastic casing by a threaded plastic to steel coupling. These protective measures are necessary because thermoplastic casing shatters easily at low temperatures and because the sun's ultraviolet rays can significantly reduce the impact strength of thermoplastic casing.

Care should be taken when grouting a well constructed with thermoplastic casing because thermoplastics deform and lose strength at relatively low temperatures.

CONCRETE WATER WELL CASING

Concrete water well casing, also called curbing, consists of either precast concrete pipe or concrete which has been poured-in-place. This type of casing should be used only for the construction of dug wells.

Precast concrete pipe that is used for well casing should;

(1) be at least 3 inches thick
(2) meet or exceed ASTM C67 Class III specifications
(3) be free of blemishes that could impair the integrity of the well

Joints between pipe segments should be sealed with a continuous, solid ring rubber gasket having a circular cross section with a diametrical tolerance of plus or minus one-sixty-fourth of an inch. Gaskets should have sufficient volume to substantially fill the recessed area when the pipe joint is assembled. A properly sized gasket will form a pressure tight seal when it is compressed between the pipe segments.

Poured-in-place casing should be at least six inches thick and be free of voids. Vertical and horizontal reinforcement should be provided, using three-eighths-inch steel rods on twelve-inch centers. Rods should lap twelve inches but such lap should not occur at construction joints. There should be no construction joint within ten feet of the original ground surface and, when possible, the walls should be poured in one continuous operation. When construction joints are required, they should be left rough and should be washed and brushed with neat cement grout before the pouring of concrete is continued. The concrete should be composed of clean, hard, durable aggregate with not less than five sacks of Portland cement per cubic yard of concrete. The diameter of the aggregate particles should not exceed either 1/5 the minimum thickness of the casing or 1 1/2 inches, whichever is less. The volumetric ratio of coarse aggregate to fine aggregate (passing No. 4 U. S. Standard Sieve) should neither exceed 2 to 1 nor be less than 1 to 2. Generally, a ratio of 1 1/2 to 1 is appropriate.

WELL SCREEN

This section consists of the following subsections:

- General Considerations
- Screen Materials and Construction
- Aperture Size
- Length
- Joints
- Sealing the Bottom of the Screen
- Methods of Installation

GENERAL CONSIDERATIONS

Well screens are necessary for all drilled wells that are completed in unconsolidated formations. Wells completed in bedrock do not require a screen unless the bedrock formation is brittle in nature or has a potential for collapse.

The three basic forces applied to a water well screen are column load (vertical compression), tensile load (extending forces), and collapse pressure (horizontal forces). These three forces should be considered when choosing a well screen.

The well screen should be installed at a depth corresponding to the depth of the most permeable zone or zones which can yield the required quantity of potable water. These zones should be determined from the driller's log. For relatively thin aquifers, it is advisable to set the screen in the lower portion of the aquifer. For aquifers that are several tens of feet thick, however, it may not be necessary to set the screen near the bottom of the aquifer.

The well screen aperture openings, screen length, and diameter should be selected so as not to limit the aquifer's water yielding characteristics while preventing access of soil particles that would detract from well efficiency and yield.

SCREEN MATERIALS AND CONSTRUCTION

The materials to be used as screens should meet strength requirements and be corrosion resistant. "To reduce the possibility of corrosion, the well screen and its end fittings should be fabricated of the same material (Type 304 Stainless Steel, Silicon Bronze, Silicon Red Brass, Monel 400, Armco Iron, Mild Steel, Plastic, etc.)" (U.S. EPA, 1975). Type 304 stainless steel is recommended due to its corrosion resistance and strength. A less expensive plastic screen may be used where strength is not an issue. A chemical analysis of the water will aid in the determination of an appropriate screen material. A screen with defects such as rough edges or gouges can promote corrosion and therefore should not be used.

Well screens should be constructed by one of the methods described below:

(1) WIRE-WOUND, CONTINUOUS SLOT SCREENS: continuous-slot well screens should be of all-welded construction. Special shaped wire shall be helically wound around an array of equally spaced longitudinal rods and welded at each point of intersection. The inlet-slot openings between adjacent turns of the outer wire should widen inwardly so as to be nonclogging (AWWA, 1984).

(2) REINFORCED WIRE WRAPPED PUNCHED PIPE: the screen should consist of perforated pipe reinforced with longitudinal bars and wrapped with wire, the wire having a crosssection such as to form between each two adjacent loops of wire an opening so shaped as to increase in size as the slot extends inward. The wire will be firmly attached to the bars which are attached to the pipe (U.S. EPA, 1975).

Other well screen types should be used only if strength requirements so dictate. These well screens should be constructed by one of the methods described below:

(1) PUNCHED (WITH MATERIAL REMOVED) AND SLOTTED PIPE: the screen should consist of a pipe that has been punched (with the material removed) or slotted by saw, mill, casting, or other similar means. The slots should be equal in width as nearly as practical, if slotted, or of uniform spacing and dimension, if punched (U.S. EPA, 1975).

(2) LOUVRED PIPE: the screen should consist of a pipe that has punched openings in it where material has not been removed. The openings formed should be between the corner of the outside of the pipe and the punched-out area, and the corner of the inside of the punched portion and its side. The openings should be uniform (U.S. EPA, 1975).

APERTURE SIZE

The aperture size is determined by the uniformity coefficient of the aquifer. "The uniformity coefficient is a numerical expression of the variety in particle sizes in mixed natural soils, defined as the ratio of the sieve size on which 40 percent by weight of the material is retained to the sieve size on which 90 percent of the material is retained" (Driscoll, 1986). Total aperture area should be sized appropriately in order to maintain an aperture (slot) entrance velocity equal to six feet per minute or less. The screen aperture size should be determined using the following criteria excerpted from Manual of Water Well Construction Practices (U.S. EPA, 1975):

(1) "Where the uniformity coefficient of the aquifer is greater than 6 and the aquifer is overlain by an essentially non-cavinq formation, the aperture size shall be that which retains 30 percent of the aquifer sample.

(2) "Where the uniformity coefficient of the aquifer is greater than 6 and the aquifer is overlain by a readily caving formation, the aperture size shall be that which retains 50 percent of the aquifer sample.

(3) "Where the uniformity coefficient of the aquifer is 3 or lower and the aquifer is overlain by an essentially non-caving formation, the aperture size shall be that which retains 40 percent of the aquifer sample.

(4) "Where the uniformity coefficient of the aquifer is 3 or lower and the aquifer is overlain by a caving formation, the aperture size shall be that which retains 60 percent of the aquifer sample.

(5) "For conditions between the extremes listed, the contractor shall interpolate to obtain the proper screen aperture size.

(6) "Where a formation to be screened has layers of differing grain sizes and gradations, use the following rule: if the 50 percent sieve size of the coarsest layer is less than 4 times the 50 percent sieve size of the finest layer, the aperture size shall be selected on the basis of the finest layer, or for each specific layer as indicated in (1), (2), (3), (4), or (5), above.

(7) "If the water is corrosive or the accuracy of the chemical analysis is in doubt, select an aperture size that will retain 10 percent more than is indicated in the above paragraphs.

(8) "Where fine sand overlies coarse sand, use the fine sand size aperture for the top 2 feet (61 cm) of the underlying coarse sand. The coarse size aperture shall not be larger than twice the find sand size."

LENGTH

The maximum yield from a private well is very small compared to a public water well; therefore, the screen length only has to be long enough to satisfy an aperture (slot) entrance velocity of 6 feet per minute or less. The minimum length of a well screen can be determined by the following formula (AWWA, 1984):

$$L = \frac{Q}{A_e V_e \text{ (7.48 gallons/ft}^3\text{)}}$$

where: L = length of screen (ft)
Q = quantity specified (gpm)
Ag= effective aperture area per foot of screen square feet (the effective aperture area shall be taken as one-half the total aperture area (sq. ft/ft)
Vg= design entrance velocity (ft/min)

Any type of joint, whether it be screen to screen or screen to casing, should be accomplished by threaded and coupled joints or electric arc or acetylene welding (U.S. EPA, 1975). These joints should be straight, tight enough to retain aquifer materials, and strong enough to maintain screen strength. A self-sealing neoprene or rubber seal attachment to the screen top may be used when joining the screen to the casing.

SEALING THE BOTTOM OF THE SCREEN

The following are acceptable methods of sealing the bottom of the screen:

(1) "BAG CEMENT METHOD: A pipe extension at least four nominal diameters in length shall be attached to the bottom of the deepest screen (the drill hole having been deepened to accommodate the extension). The bottom shall then be sealed by lowering into the extension pipe sufficient dry cement in small cloth bags to fill it to a depth of at least three nominal diameters, packing it firmly into place.

(2) "SELF-CLOSING VALVE METHOD: The bottom of the deepest screen shall be sealed by means of a self-closing valve on the bottom of the screen."

(3) "FABRICATED PLUG METHOD: The bottom of the deepest screen shall be sealed with a threaded or welded plug or point made of the same material as the screen body.

(4) "WELDED PLATE METHOD (CASING MATERIAL): The bottom of the deepest screen shall be closed by welding to it a plate of the same material as the casing and of the same thickness.

(5) "WELDED PLATE METHOD (SCREEN MATERIAL): The bottom of the deepest screen shall have a plate of the same material as the screen welded to it to seal it" (U.S. EPA, 1975).

METHODS OF INSTALLATION

The following are acceptable methods for installing well screens:

(1) PULL BACK METHOD: "the screen shall be lowered through the casing by means of a cable attached by a hook to the bail in the bottom of the screen, or by attaching a pipe to a threaded fitting in the bottom of the screen, and lowering the pipe with the screen. A heavy steel bar or line of pipe may be set on the screen bottom to hold it down while the casing is being raised. The casing shall be raised until the screen is exposed to the aquifer with the packer or seal lapped 12 inches into the casing" (U.S. EPA, 1975). In order for the screen to be exposed without it slipping out the bottom of the casing, a riser pipe attached to the top of the screen may be needed.

(2) WASHING METHOD; "the screen shall be fitted with a self-closing valve on the bottom. Next, the screen shall be attached to the well casing. A smaller pipe shall then be placed in the screen and by a method selected by the contractor also fitted to the self-closing valve. The screen with its casing shall then be 'washed' into place by pumping drilling fluid through the inner pipe" (U.S. EPA, 1975).

(3) DRIVEN THROUGH CASING METHOD: "the casing shall be set at a level immediately above the top of the formation or portion of the formation to be screened. A well point screen shall be lowered through the casing to the top of the formation by a cable and hook or an attached string of pipe. The screen shall then be seated in the formation by driving it to the desired depth and sealing it to the casing" (U.S. EPA, 1975). It should be noted that there is a potential for damaging the screen when this method is used.

(4) BAILED THROUGH CASING METHOD: "the casing shall be placed at a level immediately above the top of the formation or portion of the formation to be screened. The screen and attachments shall then be lowered through the casing to the top of the formation by cable and hook or an attached string of pipe. The screen shall then be put into place by bailing the aquifer material out from under it and allowing it to settle. After the screen is in place, it shall be sealed to the casing and the bottom plugged" (U.S. EPA, 1975). The string of pipe will help sink the screen if the weight of the screen alone is not enough. Also, continuous bailing permits the screen to settle more easily. It should be noted that any interruption during installation may cause sand to pack around the screen, preventing it from moving any further.

(5) BAILED OR AIR JETTED THROUGH CASING METHOD: “the casing shall be placed at a level immediately above the top of the formation or portion of the formation to be screened. A bail-down shoe shall be attached to the screen and a line of bail-down pipe attached to the shoe by a right and left-hand coupling, or similar release device. The screen shall then be lowered by the bail-down pipe to the top of the aquifer and then bailed into place or seated by blowing air through the bail-down pipe. When the screen has reached the desired depth, the bail-down shoe shall be plugged at the bottom by an approved method, and the screen shall be sealed to the casing" (U.S. EPA, 1975).

(6) WASHED THROUGH CASING METHOD: "the casing shall be placed at a level immediately above the top of the formation to be screened. The screen shall be fitted with a self-closing valve at the bottom and a small inner pipe attached to the valve. The screen shall be lowered through the casing by any means deemed appropriate. The screen shall be washed into place by pumping drilling fluid through the inner pipe. It shall then be sealed to the casing" (U.S. EPA, 1975).

(7) SUSPENDED FROM SURFACE METHOD: "the screen, with closed bottom, shall be attached by an approved manner to the casing and lowered into the well with the casing. In no instance shall it be driven or forced. It shall remain suspended from the surface until the formation has collapsed against it or until a filter material or formation stabilizer has been added" (U.S. EPA, 1975).

WELL DEVELOPMENT

All drilling methods alter the hydraulic characteristics of the formation materials adjacent to the borehole, impairing the transmission of water from the aquifer into the well. The reduced hydraulic conductivity may be caused by the physical rearrangement of the formation materials adjacent to the boring, or by the invasion of drilling fluids or fine sediment into the surrounding formation. Well development removes clay, silt, and fine sand, from the formation adjacent to the well intake and restores the natural properties of the aquifer. Ultimately, proper well development maximizes the specific capacity of a well and minimizes the pumping of sediment.

Well development should be accomplished by overpumping, backwashing, surging, jetting, air lift pumping, or any combination of these methods. Development should proceed until all drilling fluids are removed, and sediment-free water (water containing no more than 5 mg/L of sediment) can be obtained when the well is pumped at the designed production rate. Regardless of the method used, well development should be initiated gently and gradually increased in vigor as development proceeds.

Although the benefits of development are generally more substantial for wells completed in unconsolidated formations, all wells should be developed by the contractor prior to conducting a pumping test.

Well design and the character of the subsurface materials determine which method or methods of well development are most appropriate. Highly stratified, coarse grained aquifers, for example, are most effectively developed by methods that concentrate energy on small parts of the formation. Uniform deposits, on the other hand, are most effectively developed by methods that utilize strong surging forces over the entire well bore. Powerful surging of a well completed in a formation containing a significant amount of silt or clay, however, may actually reduce the hydraulic conductivity of the formation.

During development, a pump is subjected to sand pumping which causes excessive wear on the pump and may cause it to become sand locked either during the pumping operation or after the pump has been shut off. In order to prevent damage to the permanent pump, a test pump should be used for well development.

Time limits should not be placed on development because incomplete development may lead to premature incrustation of the well screen or cementation of the adjacent formation. The rate and effectiveness of the procedure depend on the physical characteristics of the aquifer, the depth of the well and the properties of the drilling fluid.

WATER QUANTITY (PUMPING TEST)

This section consists of the following subsections:

- General Considerations
- Pumping Test Report
- General Recommendations for Conducting Pumping Tests
- Testing Procedure
- Additional Considerations

GENERAL CONSIDERATIONS

A properly constructed private water supply well must have a sufficient capacity to provide for anticipated needs. In order to determine if the well can provide an adequate supply of water and to obtain information necessary for the design of the permanent production pump, the well driller or pump contractor should perform a pumping test. This test also provides information that may assist a contractor if the well malfunctions.

Many local regulations specify a minimum well yield required for the issuance of a building permit. Fixed minimum yield requirements, however, do not take into consideration variations in the storage capacity of the well casing and variations in household size. These factors should be considered when evaluating the adequacy of a well to meet household water supply needs.

PUMPING TEST REPORT

All pumping test data should be recorded and included in a report that the contractor should submit to the well owner, if the well driller performs the pumping test, a copy of the pumping test report should be appended to the Water Well Completion Report that is submitted to the local Board of Health and the Division of Water Resources.

The Pumping Test Report should include, but not be limited to, the following information:

(1) name and address of the well owner
(2) well location, referenced to at least two permanent structures or landmarks
(3) date the pumping test was performed
(4) depth at which the pump was set for the test
(5) location of the discharge line
(6) the static water level immediately before pumping commenced
(7) the discharge rate and, if applicable, the time the discharge rate changed
(8) pumping water levels and respective times after pumping commenced
(9) the maximum drawdown during the test
(10) the duration of the test, including both:
  a) the pumping time, and
  b) the recovery time during which measurements were taken
(11) recovery water levels and respective times after cessation of pumping
(12) reference point used for all measurements

GENERAL RECOMMENDATIONS FOR PERFORMING PUMPING TESTS

The following general recommendations apply to all pumping tests:

(1) upon completion of drilling and developing the well, and prior to beginning the pumping test, the aquifer should be allowed to recover from stresses induced by drilling and development procedures

(2) a temporary pump should be used for the test

(3) the discharge line should be located where it will not cause recirculation of pumped water

(4) before starting the pumping test, the discharge line should be filled with water to prevent unnecessary fluctuations in the discharge rate at the beginning of the test

(5) the discharge water should be checked periodically for sediment: excessive sediment in the discharge, which could damage the pump, indicates that the well needs additional development

(6) water level measurements should be measured in feet and hundredths of a foot

(7) water levels should be monitored in any test wells or supply wells that could potentially be influenced by the well being tested

TESTING PROCEDURE

This subsection consists of the following parts:

- Calculation of the Required Volume
- Pumping Test
- Examples

Calculation of the Required Volume

The pumping test should demonstrate that the well can yield the Required Volume of water within a 24 hour period. The Required Volume is calculated as follows:

(1) determine the volume of water necessary to support the household's daily needs using the following equation:

(number of bedrooms plus one bedroom) x (110 gallons per bedroom) x
(a safety factor of 2) = number of gallons needed daily

(2) determine the storage capacity of the well using the measured static water level and the depth and radius of the drillhole or casing

(3) calculate the Required Volume by adding the volumes of water in (1) and (2),above. It is this volume of water that must be pumped from the well within a 24 hour period.

Table 3 provides values that are useful in determining the storage capacity of a well; Table 4 provides flow volumes in gallons per minute and corresponding flow volumes in gallons per day.

Pumping Test

The pumping test may be conducted at whatever rate is desired. Following the pumping test, the water level in the well must be shown to recover to within 85 percent of the prepumped static water level within a 24 hour period.

If the well fails to yield the Required Volume within a 24 hour period, or if the water level in the well fails to recover to within 85 percent of the prepumped static water level within a 24 hour period, the well should be redeveloped, hydrofractured, and/ or deepened. After completing the chosen procedure (s), another pumping test should be conducted.

Examples

Example 1: For a 1 bedroom house with a well that is eight (8) inches in diameter and contains 200 ft. of standing water:

(1) (1 bedroom + 1 bedroom) = (2 bedrooms) x (110 gallons per bedroom) x (2) = 440 gallons needed daily.

(2) the volume of an 8 inch well is 2.60 gallons for every foot of length. Therefore, (200 ft. of standing water) x (2.60 gal/ft.) = 522 gallons.

(3) 440 gallons + 522 gallons = <u>962 gallons</u> that must be pumped from the well in 24 hours or less to demonstrate suitable capacity.

Example 2: For a 4 bedroom house with a well that is six (6) inches in diameter and contains 100 ft. of standing water:

(1) (4 bedroom house + 1 bedroom) = (5 bedrooms) x (110 gallons per bedroom) x (2) = 1100 gallons needed daily.

(2) the volume of a 6 inch well is 1.48 gallons for every foot of length. Therefore, (100 ft. of standing water) x (1.48 gal/ft.) = 148 gallons.

(3) 1100 gallons + 148 gallons == <u>1248 gallons</u> that must be pumped from the well in 24 hours or less to demonstrate suitable capacity.

ADDITIONAL CONSIDERATIONS

Experience has shown that a well producing less than 0.5 gpm (720 gpd) is a marginally dependable source of water for domestic use. It is recommended that a minimum cutoff of 0.5 gpm be established.

Due to seasonal variations in recharge of the groundwater, pumping tests performed during times of seasonally high ground water may not accurately predict performance during times of reduced water availability. A well that passes a pumping test in the spring, during high water-table conditions, may not be able to provide an adequate supply in summer or during drought periods when the water table is lower. Tests performed between June and October are more reliable for determining if a well will satisfy household water demands than tests performed at other times of the year.

TABLE 3
GALLONS OF WATER PER FOOT OF DEPTH
FOR VARIOUS CASING OR HOLE DIAMETERS

DIAMETER OF WELL CASING IN INCHES	GALLONS OF WATER PER FOOT OF WATER DEPTH	PER 100 FEET OF WATER DEPTH	WELL DIAMETER IN FEET	GALLONS OF WATER PER FOOT OF WATER DEPTH
1 ½	0.092	9.2	2	23.5
2	0.163	16.3	3	52.9
3	0.367	36.7	4	94.0
4	0.653	65.3	5	146.9
5	1.020	102.0	6	211.5
6	1.469	146.9	7	287.9
8	2.611	261.1	8	376.0
10	4.080	408.0	9	475.9
12	5.876	587.6	10	587.6

TABLE 4
FLOW VOLUMES IN GALLONS PER MINUTE AND
CORRESPONDING FLOW VOLUMES IN GALLONS PER DAY

Flow Volume (gpm)	Flow Volume (gpd)
0.3	432
0.4	576
0.5	720
0.6	864
0.7	1008
0.8	1152
0.9	1296
1.0	1440
1.5	2160
2.0	2880
2.5	3600
3.0	4320
3.5	5040
4.0	5760
4.5	6480
5.0	7200

PROTECTIVE WELL SEALS

This section consists of the following subsections:

- Purpose of Well Seals
- Materials
- Installation Methods
- Depth of Seals

PURPOSE OF WELL SEALS

Protective well seals consist of an impervious material (grout) that is used to seal the annular space between the casing and the borehole wall. Wells are grouted in order to protect the well from contaminated surface water; prevent the transfer of water between two water-bearing zones that differ in water quality or hydrostatic pressure; protect the well casing from corrosion, and prevent the well casing from being damaged physically by material collapsed from the borehole wall.

MATERIALS

The most appropriate material or combination of materials for a protective well seal depends on the construction of the well and the geologic and hydrologic nature of the formation or formations penetrated by the well. The composition of acceptable grouts are noted below:

(1) **Neat cement grout** is a mixture consisting of one bag (94 pounds) of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A) to not more than six gallons of clean water. Bentonite (API Standard 13A), up to two percent by weight of cement, shall be added to reduce shrinkage. Other additives, as described in ASTM Standard C494, may be used to increase fluidity and/or control setting time. Although one bag of cement to six gallons of water produces a very fluid mixture, it sets up like concrete when it hardens. Neat cement may be used in all geologic formations and is ideal for sealing small openings, for penetrating annular space outside of casings, and for filling voids in the surrounding formation. When applied under pressure, it is favored for sealing wells under artesian pressure or borings that penetrate more than one aquifer. Unlike many other grouts, neat cement will not separate into a two-phase substance.

(2) **Sand cement grout** is a mixture consisting of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A), sand, and water in the proportion of one part cement to three or four parts sand, by volume, and not more than six gallons of water per bag (94 pounds) of cement. Up to five percent, by weight, of bentonite (API Standard 13A) shall be added to reduce shrinkage.

When mixing the grout, the bentonite should be mixed with the water component of the grout first. The remaining components should then be added to the bentonite-water mixture. Although this procedure for mixing the grout is more difficult, it produces a product that is less pliable than one in which the bentonite is added after the other components have been mixed.

INSTALLATION METHODS

It is recommended that positive placement methods be used to install well seals rather than gravity placement or installation using a dump bailer. Furthermore, placement should be from the bottom of the section being grouted upward and should be completed in one continuous operation. The following methods are recommended for installing well seals:

(1) **Positive Placement Exterior Method** (Figure 7): "Grout material shall be placed by a positive displacement method such as pumping or forced injection by air pressure (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). Grout shall be injected in the annular space between the inner casing and either the outer casing or the borehole. The annular space must be a minimum of 1 1/2 inches (3.81 cm) for sand cement or neat cement grout, and not less than three times the size of the largest coarse aggregate used. The grout pipe shall extend from the surface to the bottom of the zone to be grouted. The grout pipe shall have a minimum inside diameter of one inch for sand cement or neat cement grout. Grout shall be placed, from bottom to top, in one continuous operation. The grout pipe may be slowly raised as the grout is placed but the discharge end of the grout pipe must be submerged in the emplaced grout at all times until grouting is completed. The grout pipe shall be maintained full, to the surface, at all times until the completion of the grouting of the entire specified zone. In the event of interruption in the grouting operations, the bottom of the pipe should be raised above the grout level and should not be resubmerged until all air and water have been displaced from the grout pipe and the pipe flushed clean with clear water. Curing time before construction may be resumed: Portland Cement Type I-minimum 72 hours; Type II-minimum 36 hours (U.S. EPA, 1975).

(2) **Continuous Injection Method** (Figure 8): "Grout shall be placed by the float shoe continuous injection method (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The bottom of the casing shall be fitted with a suitable drillable float shoe equipped with a back pressure valve. Tubing or pipe shall be run to the float shoe to which it shall be connected by a bayonet fitting, left hand thread coupling, or similar release mechanism. Water or other drilling fluid shall be circulated through the tubing and up through the annular space outside the casing. When the annular space is clean and open, grout shall be pumped down the pipe or tubing and forced by continual pumping out into the annular space surrounding the casing. Pumping shall continue until the entire zone to be grouted is filled. The grout pipe shall then be detached from the float shoe and raised to the surface for flushing. After the grout has set the float shoe, the back pressure valve, and any concrete plug remaining in the bottom of the casing shall be drilled out. A neat cement or sand cement grout shall be used for this procedure with a minimum annular space of 1.5 inches completely surrounding the casing. Curing time required before construction may be resumed shall be 72 hours for Type I Portland Cement and 36 hours for Type III" (U.S. EPA, 1975).

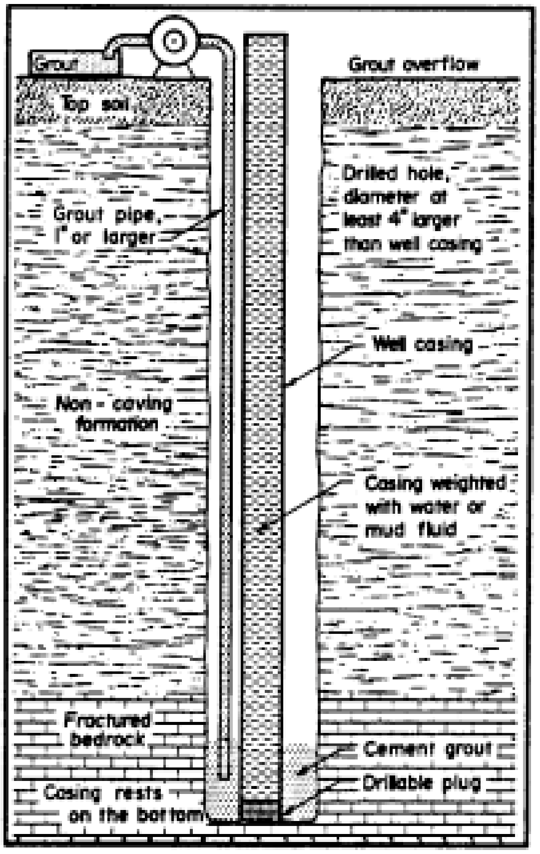

Figure 7: Grout Installation by Positive Placement Exterior Method. Grout is pumped through a pipe lowered into annular space outside the casing. (Johnson 1966)

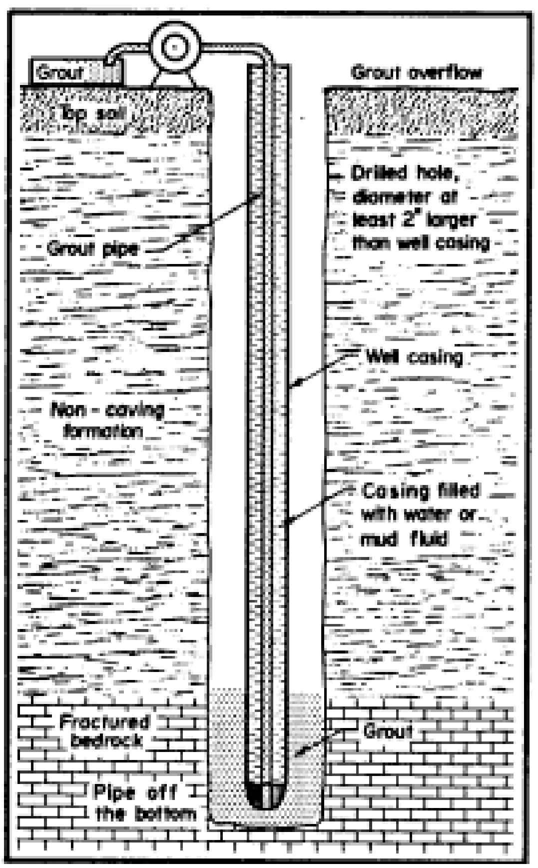

Figure 8: Grout Installation by Continuous Injection Method: Grout pipe placed inside the casing is connected to a drillable plug or float shoe at the bottom of the casing. (Johnson, 1966)

(3) **Positive Placement Interior Method with Upper Plug, Lower Plug or Two Plugs**: In the upper plug method, a measured quantity of grout, sufficient to seal the casing in place, is pumped into the capped casing. Because the grout is in direct contact with the drilling fluid, there is a narrow zone of weak grout between the drilling fluid and the stable grout. In order to prevent the weak zone at the grout-drilling fluid interface from being located at the critical position at the bottom of the casing, the casing should be uncapped; a drillable plug, constructed of plastic or other suitable material, should be inserted on top of the grout; and the casing should be recapped. A measured volume of water, equal to the volume of the casing, should then be pumped into the casing, forcing the plug out the bottom of the casing.

In the lower plug method (Figure 9), the casing is uncapped; a drillable plug, constructed of plastic or other suitable material, is inserted; and the casing is recapped. A measured quantity of grout, sufficient to seal the casing in place, is then pumped into the capped casing followed by a volume of water sufficient to force most of the grout out the bottom of the casing and up the annular space. A common practice is to leave 10 to 15 feet of grout in the casing.

In the two plug method, which is a variation of the two preceding methods, the casing is uncapped, a drillable plug is inserted, and the casing is recapped as in the lower plug method. A measured volume of grout, sufficient to seal the casing in place, is pumped into the casing. The casing is then uncapped, a second plug is inserted, and the casing is recapped. A measured volume of water slightly less than the volume of the casing is then pumped into the casing until the second, or uppermost of the two plugs, is pushed out the bottom of the casing, and the grout is forced upward into the annular space

In all three of these methods, grout should be placed after water or other drilling fluid has been circulated in the annular space for a sufficient period of time to clear obstructions. Backflow should be prevented by maintaining constant pressure within the casing until the grout has set. Pressure should be maintained for a minimum of 24 hours or until such a time that a sample of grout indicates a satisfactory set. Minimum curing times recommended before construction may be resumed are: 72 hours when Type I Portland cement is used in the grout, and 36 hours when Type III Portland cement is used

(4) **Positive Placement Interior Method with Capped Casing** (Figure 10): "Grout shall be placed by pumping or air pressure injection through the grout pipe installed inside the casing from the casing head to a point 5 feet (1.5 m) above the bottom of the casing (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The grout pipe shall extend airtight, through a sealed cap on the casing head of the well casing. The casing head shall be equipped with a relief valve and the drop pipe shall be equipped at the top with a valve permitting injection. The lower end of the drop pipe and the casing shall be open. Clean water shall be injected down the grout pipe until it returns through the casing head relief valve. The relief valve is then closed and injection of water is continued until it flows from the borehole outside of the casing to be grouted in place. This circulation of water is intended to clean the hole and condition it to better take the grout. Without significant interruption, grout shall be substituted for water

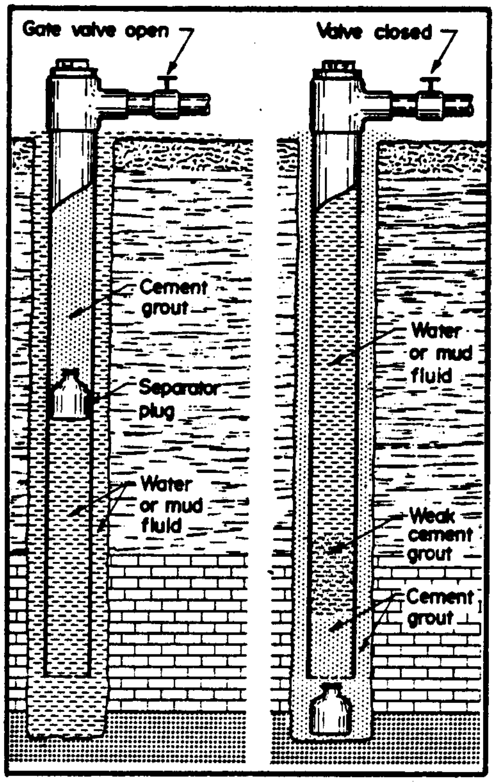

Figure 9: Grout Installation by Positive Placement Interior Method with Lower Plug. A plug, placed inside the casing, separates the drilling fluid from the grout, which is installed above the plug. As the grout fills the casing, the plug is forced out of the bottom and grout moves upward in the annular space. (Johnson 1966)

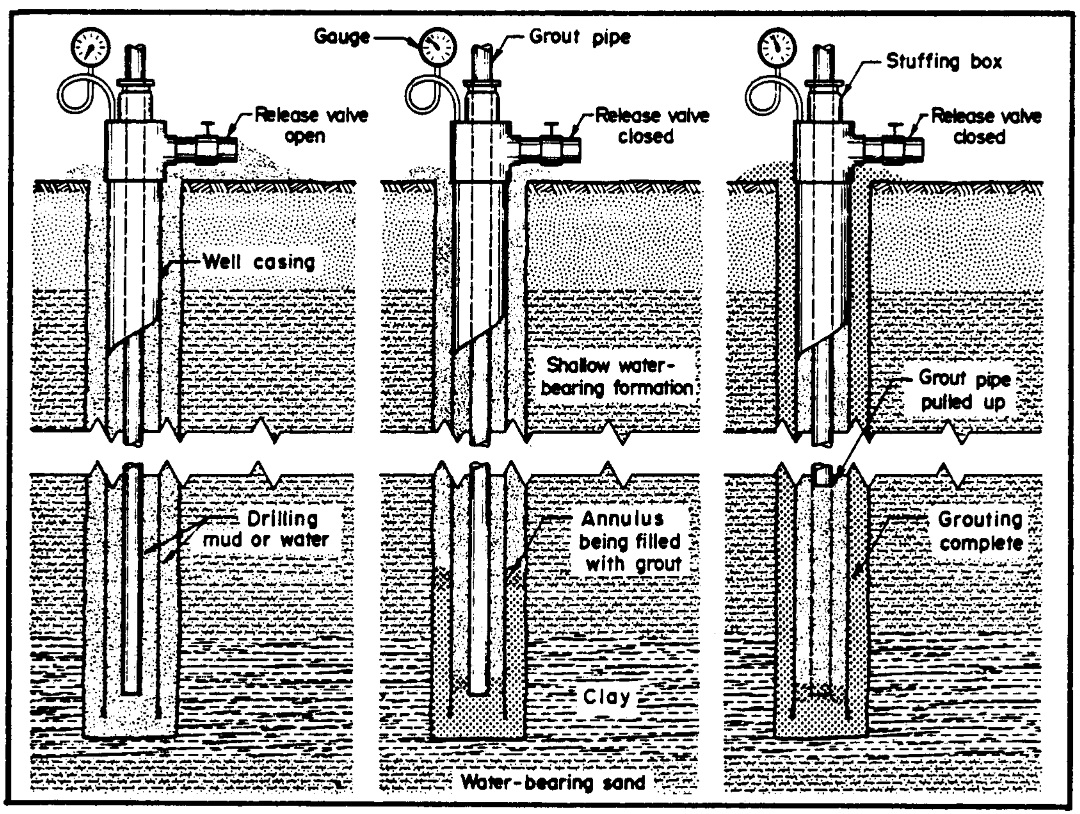

Figure 10: Grout Installation by Positive Placement Interior Method with Capped Casing (Pressure Grouting). Pressure is maintained until the grout hardens. (Johnson 1966)

and, in a continuous manner, injected down the grout pipe until it returns to the surface outside of the casing. A small amount of water, not to exceed seventeen gallons per hundred lineal feet (30 m) of 2 inch (5.08 cm) drop pipe may be used to flush the grout pipe, but pressure shall be maintained constant on the inside of the grout pipe and the inside of the casing until the grout has set. Pressure shall be maintained for at least 24 hours, or until such time as a sample of the grout indicates a satisfactory set. Neat cement or sand cement grout shall be used for this procedure with a minimum annular space of 1 1/2 inches (3.8 cm) completely surrounding the casing. Curing time before construction may be resumed; Portland Cement Type I-minimum 72 hours; Type III-minimum 36 hours" (U.S. EPA, 1975).

DEPTH OF SEALS

All wells completed with the casing extending above grade should have a surface seal designed to eliminate the possibility of surface water flowing down the annular space between the well casing and the surrounding backfilled materials. The surface seal should extend to a depth below the local frost line. Private wells completed in bedrock should be grouted from the top of the weathered rock interface to 15 feet into competent bedrock.

WELLHEAD COMPLETION

This section consists of the following subsections:

- Upper Terminus of Well Casing
- Sanitary Seal or Well Cap
- Access Port or Pressure Gage Fitting
- Well Vent
- Below-Grade Connections
- Above-Grade Connections
- Surface Grading of Well Site

UPPER TERMINUS OF WELL CASING

Well casing terminating above-grade should extend at least 12 inches above the predetermined ground surface at the wellhead except when the well is located in a floodplain. When a well is located in a floodplain, the well casing should extend at least 2 feet above the level of the highest recorded flood. The top of the well casing should be reasonably smooth and level.

Well casing should not be cut off below the land surface unless a pitless adapter or a pitless unit is installed; or an abandoned well is being permanently plugged. If the casing of an existing well is terminated below the land surface and is not connected to a pitless adapter or a pitless unit, the well owner should have the existing casing extended to the appropriate above ground height or have a pitless device installed.

When thermoplastic well casing is used, the portion of the casing extending above the frost line when a pitless device is not installed should either consist of steel or should be capped with an oversized steel casing extending to a level above the top of the thermoplastic casing. When steel is used for the upper terminus of a well in which a pitless adapter is not installed, the steel casing should be attached to the thermoplastic casing by a threaded plastic to steel coupling. These protective measures are necessary because thermoplastic casing shatters easily at low temperatures and because the sun's ultraviolet rays can significantly reduce the impact strength of thermoplastic casing.

SANITARY SEAL OR WELL CAP

Any well, except a dug well, that does not terminate in the base of a pump should be equipped with a sanitary seal or watertight well cap designed to prevent surface water and foreign matter from entering the well (Figures 11 and 12). A flowing artesian well should be equipped with a shut-off valve and a backflow preventer so that the flow of water can be stopped completely when the well is not in use.

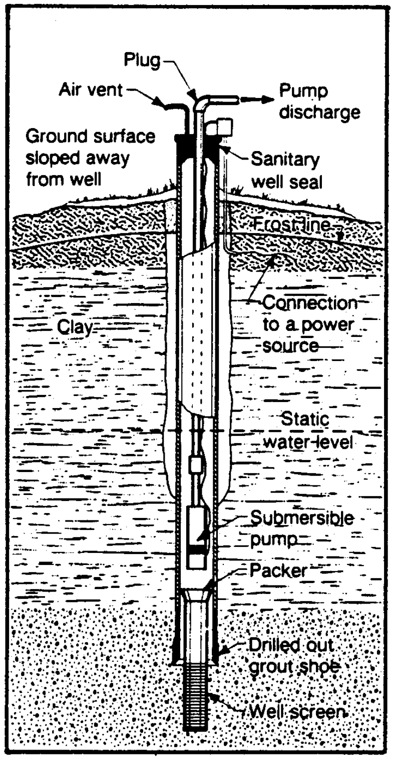

Figure 11: Properly Vented and Sealed Well (Driscoll, 1986 after U.S. EPA, 1973)

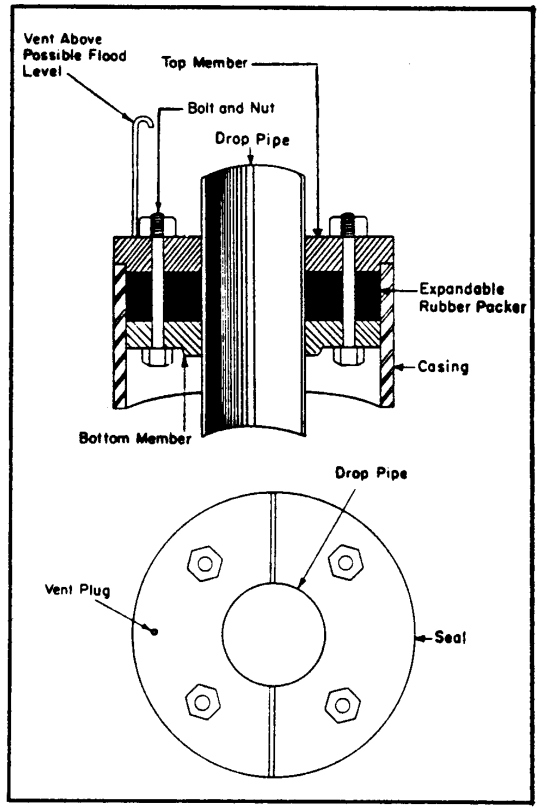

Figure 12: Detail of Acceptable Well Cap

ACCESS PORT OR PRESSURE GAGE FITTING

Except for dug wells, all new wells and wells which are repaired or altered should be equipped with an access port that will permit unobstructed measurement of the depth to the water surface or a pressure gage fitting that will permit access for measurement of shut-in pressure of a flowing artesian well. Pressure gage fittings should include a control valve so that the pressure gage can be removed. Access ports should have an inside diameter greater than or equal to one-half of an inch and should be fitted with a threaded plug or a threaded cap. Figure 13 illustrates recommended locations for access ports and pressure gage fittings. Air lines and removable well caps are acceptable as access ports. When a spool type of pitless adapter is used which prevents the casing from having an unobstructed opening to the water surface, a three-fourths-inch diameter pipe may be attached to the spool and extended to the surface below the well cap in order to facilitate measurement of the water surface.

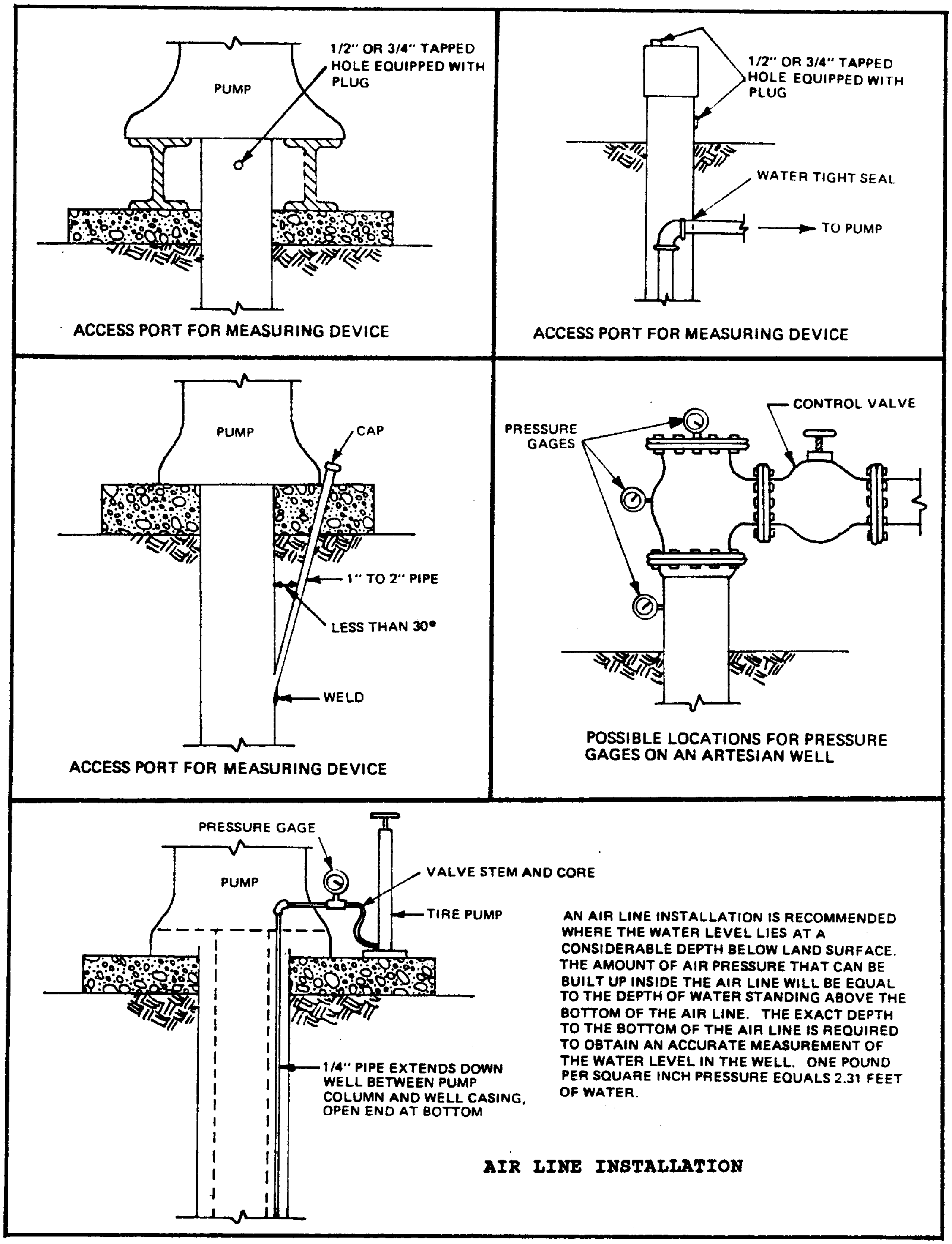

Figure 13: Suggested Methods for Installing Access Ports and Pressure Gages for Measuring Water Levels in Wells

WELL VENT

All wells except flowing artesian wells and dug wells should be vented. The opening of the vent pipe should be covered with a 24 mesh corrosion resistant screen and should be large enough to prevent water from being drawn into the well through electrical conduits or leaks in the seal around the pump when the pump is turned on. The vent pipe should terminate in a downward position at or above the top of the casing.

BELOW-GRADE CONNECTIONS

All connections to a well casing made below ground should be protected by a pitless adapter or a pitless unit that complies with the most recent revision of National Sanitation Foundation Standard Number 56, entitled "Pitless Well Adapters." Native materials should be packed tightly around the pitless device after it has been installed and the necessary connections have been completed.

A below-grade connection should never be submerged in water at the time of installation and all piping should be protected against freezing. Any buried lines between the well and the pump should be enclosed in a watertight conduit and it is recommended that the conduit be pressurized. Protective conduits may terminate at the end of the horizontal line entering a basement provided that the elevation of the pipe entrance is at least two feet above the basement floor and the basement is not subject to flooding.

ABOVE-GRADE CONNECTIONS

Above-grade connections into the top or side of a well casing should be at least 12 inches above the established ground surface or two feet above the level of the highest recorded flood, whichever is higher. Above-grade connections should be sealed so that they are watertight. One or more of the following techniques should be used to ensure that an above-grade connection is watertight; (1) a threaded connection, (2) a welded connection, (3) a rubber expansion sealer, (4) bolted flanges with rubber gaskets, and (5) extension of the casing at least one inch into the base of a pump that is mounted and sealed on a concrete pedestal.

SURFACE GRADING OF WELL SITE

In order to prevent ponding of water around the well casing and to drain surface water runoff away from the wellhead, the ground immediately surrounding the well casing should be sloped away from the well in all directions. When earth materials are used for surface grading, they should be firmly compacted.

PUMPS

This section consists of the following subsections:

- Pump Types
- Pump Installation

PUMP TYPES

Pump selection is based primarily on the design, depth, and yield of the well. Pumps may be broadly classified as shallow-well, deep-well, or positive displacement pumps. Shallow-well pumps, which can draw water from depths to about 22 feet, depend on atmospheric pressure to force water into the vacuum that the pump develops within the suction pipe. A shallow-well pump may also be used to deliver water from tanks, cisterns, and other storage vessels.

Deep-well pumps utilize pistons, impellers, or jets to lift, or push, the water upward. The depth from which deep-well pumps can obtain water depends on the design of the pump and varies from less than 100 feet to more than 1,000 feet.

A positive displacement pump delivers water at a constant rate regardless of the pressure or distance it must overcome. It may be either a shallow-well or a deep-well design.

The following types of pumps may be used for private water supply systems.

(1) **"Submersible Multistage Pump**: several impellers (small centrifugal pumps) act in series to force water up the drop pipe. A nylon rope permits pulling the pump if the drop pipe breaks. An electric cable provides electricity to the pump motor.

(2) **"Jet Pump**: in the single-pipe jet, the well casing is the return, or pressure, line. The venturi is at the motor of a shallow-well jet, but is down in the well for a deep-well jet, requiring both a suction and a return, or pressure, line.

(3) **"Centrifugal Pump**: the impeller is motor-driven to suck water into the inlet and force it out the high pressure outlet side.

(4) **"Piston Pump**: the double-acting piston pump sucks water from the well during both strokes and forces the water out the pressure side. The deep-well piston sucks water through the check valve on the upstroke and forces it past the piston on the downstroke.

(5) "**Turbine Pum**p: the deep well multistage turbine operates the same as a submersible centrifugal. Bowl, impeller, and diffuser design are modified for higher pressures.

(6) **"Helical Rotor Pump:** the rotor operates like an auger to force water up through the pump." (Midwest Plan Service, 1979).

The aforementioned pump types are illustrated in Figure 14 and additional information is provided in Table 5. It should be noted, however, that turbine pumps are not used for private water systems in Massachusetts.

Booster pumps are sometimes utilized for private water supply systems. These pumps increase pressure, but cannot increase the flow rate. A booster pump may be utilized when water lines extend a long distance from the water source instead of having high pressure at the source pump which could cause excessive pressure at outlets.

Pump selection is based on use and pressure requirements. The in-line centrifugal booster pump works best for small pressure increases and flow rates below 20 gallons per minute and the end-suction centrifugal booster pump is commonly used for both large pressure increases and high flow rates. A submersible booster pump is ideal for in-line boosting because it does not disrupt the continuity of the line or require a pump house.

PUMP INSTALLATION

All pumps should be installed either below the frost line with a pitless adapter or in some other heated and protected sanitary location. When a pitless adapter is used, it should comply with the most recent revision of National Sanitation Foundation Standard Number 56, entitled "Pitless Well Adapters. Above-ground pumps should be installed in sheltered, dry, accessible locations and should be protected from freezing.

Shallow-well pumps should be installed as near the well or water source as possible to minimize suction lift. Deep-well reciprocating and turbine pumps must be installed directly over the well. Submersible and helical rotor pumps must be installed in the well. A deep-well jet pump may be offset from the well.

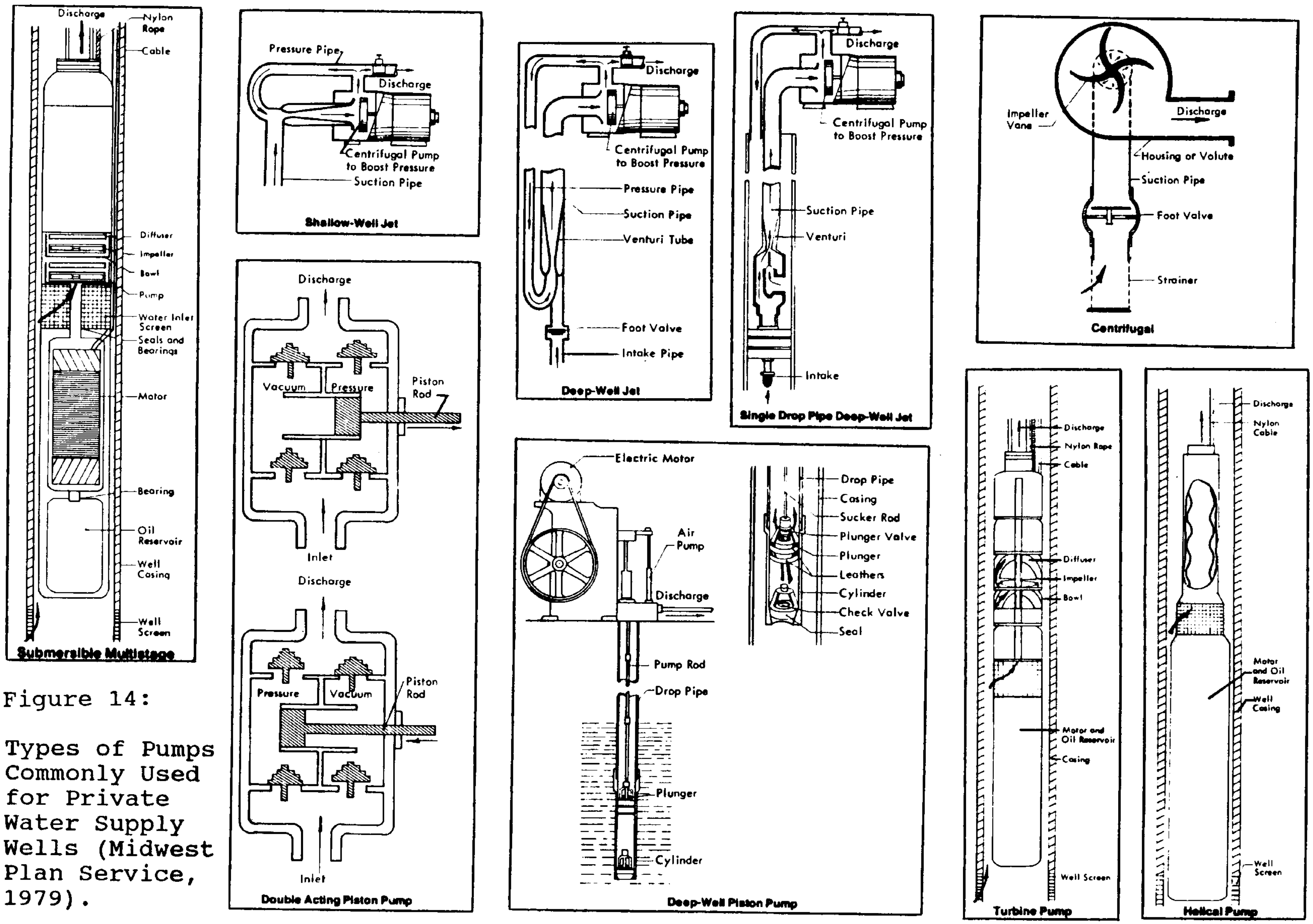

Figure 14:

Types of Pumps Commonly Used for Private Water Supply Wells (Midwest Plan Service, 1979).

TABLE 5: SUMMARY OF PUMP CHARACTERISTICS FOR PUMPS COMMONLY USED FOR PRIVATE WATER SUPPLY WELLS

	SUBMERSIBLE MULTISTAGE	JET (OR EJECTOR) SHALLOW-WELL OR DEEP-WELL	CENTRIFUGAL SHALLOW-WELL	RECIPROCATING OR PISTON SHALLOW WELL	RECIPROCATING OR PISTON DEEP WELL	DEEP WELL TURBINE MULTISTAGE	SUBMERSIBLE HELICAL ROTOR
PRACTICAL LIFT	TO 1,000	TO 22' FOR SHALLOW-WELL JET AND TO 85' FOR DEEP-WELL JET. DEEPER DEEP-WELL JETS ARE POSSIBLE BUT LESS EFFICIENT.	TO 15'	TO 22'	TO 600'	TO 1,500'	TO 1,000'
HOW IT WORKS	OPERATES LIKE A SHALLOW-WELL CENTRIFUGAL PUMP EXCEPT THERE ARE SEVERAL IMPELLERS MOUNTED CLOSE TOGETHER ON A SINGLE SHAFT. THE IMPELLERS AND MOTOR ARE IN A HOUSING IMMERSED IN THE WATER SOURCE. EACH IMPELLER AND ITS DIFFUSER (A GUIDE TO THE NEXT IMPELLER) IS CALLED A STAGE. A 4" OR LARGER CASING IS USUALLY REQUIRED.	JET PUMPS CONSIST OF A PUMP (USUALLY CENTRIFUGAL) AND A JET OR EJECTOR ASSEMBLY. THE ASSEMBLY IS IN THE PUMP FOR SHALLOW-WELL UNITS OR IN THE WELL ON DEEP-WELL UNITS. THE PUMP FORCES SOME WATER THROUGH THE NOZZLE AND VENTURI TUBE OF THE ASSEMBLY AND FORCES THE REST OF THE WATER TO THE DISTRIBUTION SYSTEM.	A ROTATING WHEEL OR IMPELLER DEVELOPS A VACUUM IN THE INTAKE PIPE. WATER FILLS THE VACUUM; THE IMPELLER INCREASES ITS VELOCITY AND FORCES IT INTO A SURROUNDING CASING SHAPED TO SLOW DOWN THE FLOW AND CONVERT THE VELOCITY TO PRESSURE.	A PISTON IS DRIVEN FROM A CHAMBER TO DEVELOP A VACUUM. WATER FILLS THE VACUUM AND IS FORCED INTO THE WATER SYSTEM AS THE PISTON REVERSES DIRECTION.	A PUMP CYLINDER IS ATTACHED TO THE BOTTOM OF THE DROP PIPE. A PISTON IS ATTACHED TO A ROD IN THE DROP PIPE. AS THE PISTON IS FORCED UP AND DOWN, IT PUMPS WATER UP THROUGH THE DROP PIPE.	OPERATES LIKE A CENTRIFUGAL PUMP EXCEPT THERE ARE ONE OR MORE IMPELLERS MOUNTED CLOSE TOGETHER ON A VERTICAL SHAFT. THE BOWLS (EACH BOWL IS ONE STAGE--AN IMPELLER AND ITS DIFFUSER) ARE BELOW THE PUMPING WATER LEVEL WITH THE DISCHARGE PIPE AND SHAFT EXTENDING TO THE POWER UNIT AT THE SURFACE.	A POSITIVE DISPLACEMENT PUMP MOUNTED WITH A MOTOR IN A SUBMERSIBLE HOUSING.
ADVANTAGES	PRODUCES A SMOOTH, EVEN FLOW. EASY TO FROST-PROOF. SHORT PUMP SHAFT TO MOTOR.	FEW MOVING PARTS. BOTH SHALLOW-WELL AND DEEP-WELL JETS CAN BE OFFSET FROM THE WELL. HIGH CAPACITY AT LOW HEADS.	PRODUCES A SMOOTH, EVEN FLOW. THE OPEN IMPELLER TYPE, BUT NOT THE CLOSED IMPELLER TYPE, PUMPS WATER WITH SOME SAND. USUALLY RELIABLE AND WITH GOOD SERVICE LIFE.	CAN PUMP SMALL AMOUNTS OF SAND. CAN BE INSTALLED OVER SMALL DIAMETER WELLS. POSITIVE DISPLACEMENT MEANS A CONSTANT RATE OF YIELD. ADAPTABLE TO HAND OPERATION.	SAME AS FOR SHALLOW-WELL. THE OPEN-TYPE CYLINDER IS EASY TO MAINTAIN.	PRODUCES A SMOOTH, EVEN FLOW. EASY TO FROST-PROOF. LONG DRIVE SHAFT REQUIRES A STRAIGHT AND VERTICAL WELL CASING.	PRODUCES A SMOOTH, EVEN FLOW. EASY TO FROST-PROOF. SHORT PUMP SHAFT TO MOTOR. PUMPS SAND WITH LESS PUMP DAMAGE THAN ANY OTHER TYPE.
DISADVANTAGES	REPAIR TO PUMP OR MOTOR REQUIRES PULLING PUMP FROM WELL. EASILY DAMAGED BY SANDY WATER.	EASILY DAMAGED BY SANDY WATER. THE AMOUNT OF WATER RETURNED TO EJECTOR INCREASES WITH INCREASED LIFT; 50% OF THE TOTAL WATER PUMPED AT 50' LIFT AND 76% AT 100' LIFT.	LOSES PRIME EASILY. EFFICIENCY DEPENDS ON OPERATING UNDER DESIGN HEADS AND SPEED.	PULSATING DISCHARGE MAY CAUSE VIBRATION AND NOISE.	SAME AS FOR SHALLOW-WELL. THE PUMP MUST BE DIRECTLY OVER THE WELL.	PUMP REPAIR REQUIRES PULLING PUMP FROM WELL.	PUMP OR MOTOR REPAIR REQUIRES PULLING PUMP FROM WELL.
REMARKS	THESE PUMPS USUALLY OPERATE AT 3500 RPM, THE FASTEST PRACTICAL SPEED FOR A 60-CYCLE ELECTRIC MOTOR. PUMP CAPACITY DEPENDS ON IMPELLER DESIGN. PRESSURE DEPENDS ON DIAMETER, SPEED, AND NUMBER OF IMPELLERS.	CAPACITY DEPENDS ON DESIGN AND NUMBER OF IMPELLERS IN THE JET. PRESSURE DEPENDS ON DIAMETER, SPEED, AND NUMBER OF IMPELLERS.	VERY EFFICIENT FOR CAPACITIES OVER 50 GPM AND PRESSURES LESS THAN 65 PSI. IDEAL FOR A BOOSTER PUMP. CAN BE OFFSET FROM THE WELL.	PUMP CAPACITY DEPENDS ON CYLINDER SIZE (DISPLACEMENT) AND STROKES PER MINUTE. PRESSURES ARE LIMITED BY THE STRENGTH OF THE PUMPING EQUIPMENT AND THE MOTOR HORSEPOWER. CAN BE OFFSET FROM THE WATER SOURCE.	DOUBLE-ACTING BARRELS PUMP 65% MORE WATER WITH 15% MORE HORSEPOWER.	USUALLY OPERATES AT 1,760 OR 3,500 RPM, DEPENDING ON KIND OF POWER USED. USUALLY USED FOR HIGH CAPACITY FROM DEEP WELLS. CAPACITY DEPENDS ON DESIGN, DIAMETER, AND SPEED OF THE IMPELLERS. PRESSURE DEPENDS ON DIAMETER, SPEED, AND NUMBER OF IMPELLERS.	CAPACITY DEPENDS ON ROTOR DESIGN. CAN BE USED IN 4" OR LARGER WELLS.

MIDWEST PLAN SERVICE, 1979

DISINFECTION

This section consists of the following subsections;

- Purpose of Disinfection
- Responsibility for Disinfection
- Commonly Used Chlorine Compounds
- Stability of Commonly Used Chlorine Compounds
- Recommended Chlorine Concentrations for Disinfecting Wells
- Procedure for Disinfecting Wells
- Effectiveness of the Disinfection Procedure

PURPOSE OF DISINFECTION

During the construction, repair, and alteration of a well and during pump installation, maintenance, and repair, bacteria can be introduced into both the well and the aquifer. These bacteria may be pathogenic or may metabolize iron and manganese in the ground-water, and cause incrustation of the well screen or clogging of the pore space in the aquifer. The simplest and most effective way to kill harmful bacteria introduced by these activities is to disinfect the entire water supply system with a chlorine solution.

RESPONSIBILITY FOR DISINFECTION

Immediately following construction, repair, or alteration, the well driller should disinfect the well. If a pump is to be installed by the well driller immediately upon completion of the well, the driller should disinfect the well and the pumping equipment after the pump has been installed.

If the pump is not installed upon completion of the well, the pump contractor should disinfect the well and the pumping equipment after the pump has been installed. The pump contractor should also disinfect the entire water supply system after any maintenance or repair work is done on the pump.

COMMONLY USED CHLORINE COMPOUNDS

Sodium hypochlorite and calcium hypochlorite are the most common chlorine compounds used to disinfect private water supply systems. Sodium hypochlorite solutions are available in several strengths. Most household laundry bleaches consist of sodium hypochlorite dissolved in water. These solutions generally contain 5% to 5.25% available chlorine and can be purchased at most grocery stores. Stronger sodium hypochlorite solutions, containing 12% to 12.5% available chlorine, are sold for use in water and wastewater treatment plants, and for use in swimming pools.

The calcium hypochlorite compound used most often by water well and pump contractors is known as high-test calcium hypochlorite. This compound is available as granules or tablets which commonly contain 65% by weight available chlorine.

STABILITY OF COMMONLY USED CHLORINE COMPOUNDS

The chlorine compounds commonly used in preparing disinfectant solutions are not stable. Therefore, outdated products or compounds which have been improperly stored should never be used to prepare solutions with specified chlorine concentrations.

Sodium hypochlorite is so unstable as a dry compound that it can be purchased only as a solution. Sodium hypochlorite solutions, however, are also unstable. A sodium hypochlorite solution with 10% available chlorine, for example, loses chlorine at a rate such that after six months there is approximately 5% available chlorine remaining in the solution. Sodium hypochlorite solutions more than 60 days old will not contain the same chlorine concentration as the original solution and should not be used in preparing solutions with specified chlorine concentrations.

Dry calcium hypochlorite, on the other hand, is relatively stable. For example, after 12 months of storage in a cool, dry environment, properly packaged calcium hypochlorite will retain approximately 90% of the chlorine originally available in the compound. If, however, the compound becomes moist, it will lose chlorine more rapidly.

Chlorine irritates the eyes, skin, and respiratory tract. Furthermore, dry chlorine compounds become strongly corrosive in the presence of moisture. Chlorine, in solution, is a strong oxidizing agent that reacts vigorously with hydrocarbons, such as oil and grease, and other organic compounds, such as turpentine, ethyl alcohol, glycerol, carbon tetrachloride and charcoal. For safety, follow the handling instructions on the product label.

RECOMMENDED CHLORINE CONCENTRATIONS FOR DISINFECTING WELLS

When a well is disinfected, the initial chlorine concentration should be 100 mg/l throughout the entire water column. Disinfection of the distribution system, when connected, should also be accomplished using an initial chlorine concentration of 100 mg/l.

PROCEDURE FOR DISINFECTING WELLS

This subsection consists of the following parts;

- Preparation
- Determining the Required Amount of Chlorine Compound
- Mixing the Disinfectant Solution
- Placement of the Disinfectant Solution
- Retention Time for the Disinfectant Solution
- Flushing the System

Preparation

Prior to introducing disinfectant into a well, the interior of the well casing, the pump, and any piping, should be thoroughly cleaned and flushed to remove all foreign substances such as oil, grease, joint dope, soil, sediment, and scum. A thorough cleaning is necessary because only bacteria which come in contact with the disinfectant will be killed. Additionally, when chlorine comes in contact with hydrocarbons and other organic compounds which may be used during the construction and completion of a well, the reaction can be violent.

Determining the Required Amount of Chlorine Compound

(1) Determine the number of feet of water in the well.

(2) Referring to the first two columns of Tables 6 and 7, determine the number of gallons of water per feet of water in the well.

(3) Multiply the number of feet of water in the well by the number of gallons of water per foot to determine the total number of gallons of water in the well.

(4) Determine the amount of chlorine compound required to produce a disinfectant solution with the required chlorine concentration. Tables 6 and 7 provide guidance for producing a disinfectant with a chlorine concentration of 100 mg/l using compounds consisting of 5.25% sodium hypochlorite, 12% sodium hypochlorite, and 65% calcium hypochlorite. Note that the required amounts of chlorine compound indicated in Table 6 (for well diameters of one foot or less) were calculated per 100 feet of water depth while the required amounts of chlorine compound indicated in Table 7 (for well diameters of two feet or more) were calculated per foot of water depth.

For specific water volumes or for compounds consisting of concentrations different than those presented in Tables 6 and 7, the following equations apply:

(1) For Sodium Hypochlorite Compounds (liquid):

$$\text{Volume Sodium Hypochlorite Compound Required (cups)} = \frac{\text{Required Concentration}}{\text{Concentration of Compound}} \times \text{Gallons of Water in Well} \times \frac{16 \text{ cups}}{1 \text{ gallon}}$$

(2) For Calcium Hypochlorite Compounds (tablets or granules)

$$\text{Weight Calcium Hypochlorite Compound Required (ounces)} = \frac{\text{Required Concentration}}{\text{Concentration of Compound}} \times \text{Gallons of Water in Well} \times \frac{133 \text{ weight in ounces}}{1 \text{ gallon of water}}$$

Note that in both equations the Required Concentration and the Concentration of Compound should be in decimal form. For example, a required concentration of 100 mg/l = 0.0001 and a compound with a hypochlorite concentration of 5.25% = 0.0525 .

When using the equations, round off the calculated values to the nearest 1/8 cup for liquid sodium hypochlorite compounds and the nearest 0.1 ounce for dry calcium hypochlorite compounds.

Mixing the Disinfectant Solution

Once the required amount of chlorine compound has been determined, the compound should be mixed with or dissolved into clean water, being sure to add additional chlorine compound to compensate for the mixing water. If, for example, 10 gallons of water are used for mixing the compound, an additional 1/2 cup of 5.25% sodium hypochlorite solution, an additional 1/8 cup of 12% sodium hypochlorite solution, or an additional 0.2 ounces of 65% calcium hypochlorite compound should be added.

The purpose of mixing the chlorine compound with water is to ensure that, when the disinfectant solution is placed in the well, the surfaces of all components above the water level in the well will come in contact with the disinfectant. It is best to mix the chlorine compound in a plastic, ceramic, or wood container because metals are corroded by strong chlorine solutions.

TABLE 6
AMOUNT OF CHLORINE COMPOUND REQUIRED TO PRODUCE A CHLORINE CONCENTRATION OF 100 MG/L (FOR WELL DIAMETERS OF ONE FOOT OR LESS)"

DIAMETER OF WELL CASING IN INCHES	GALLONS OF WATER PER FOOT OF WATER DEPTH	GALLONS OF WATER PER 100 FEET OF WATER DEPTH	SODIUM HYPOCHLORITE REQUIRED PER 100 FEET OF WATER DEPTH (CUPS, LIQUID MEASURE) USING 5.25% SOLUTION	SODIUM HYPOCHLORITE REQUIRED PER 100 FEET OF WATER DEPTH (CUPS, LIQUID MEASURE) USING 12% SOLUTION	CALCIUM HYPOCHLORITE REQUIRED PER 100 FEET OF WATER DEPTH (OUNCES, DRY WEIGHT) USING 65% COMPOUND
1 ½	0.092	9.2	¼	1/8	0.2
2	0.163	16.3	½	1/4	0.3
3	0.367	36.7	1 1/8	1/2	0.8
4	0.653	65.3	2	7/8	1.3
5	1.020	102.0	3 1/8	1 3/8	2.1
6	1.469	146.9	4 ½	2	3.0
8	2.611	261.1	8	3 1/2	5.3
10	4.080	408.0	12 3/8	5 1/2	8.4
12	5.876	587.6	17 7/8	7 7/8	12.0

TABLE 7
AMOUNT OF CHLORINE COMPOUND REQUIRED TO PRODUCE A CHLORINE CONCENTRATION OF 100 MG/L (FOR WELL DIAMETERS OF TWO FEET OR MORE)*

WELL DIAMETER IN FEET	GALLONS OF WATER PER FOOT OF WATER DEPTH	SODIUM HYPOCHLORITE REQUIRED PER FOOT OF WATER DEPTH (CUPS, LIQUID MEASURE) USING 5.25^ SOLUTION	SODIUM HYPOCHLORITE REQUIRED PER FOOT OF WATER DEPTH (CUPS, LIQUID MEASURE) USING *12* SOLUTION	CALCIUM HYPOCHLORITE REQUIRED PER FOOT OF WATER DEPTH (OUNCES, DRY WEIGHT) USING 65« COMPOUND
2	23.5	¾	1/4	0.5
3	52.9	1 5/8	3/4	1.1
4	94.0	2 7/8	1 1/4	1.9
5	146.9	4 ½	2	3.0
6	211.5	6 ½	2 7/8	4.3
7	287.9	8 ¾	3 7/8	5.9
8	376.0	111/2	5	7.7
9	475.9	14 1/2	6 3/8	9.8
10	587.6	17 7/8	7 7/8	12.0

THE FOLLOWING INFORMATION APPLIES TO TABLES 6 AND 7:
REQUIRED AMOUNTS WERE CALCULATED USING EQUATIONS 1 AND 2 (REFER TO TEXT) AND:
(1) LIQUID MEASURES WERE ROUNDED OFF TO THE NEAREST ONE-EIGHTH CUP (1/8 CUP s 2 TABLESPOONS)
(2) DRY WEIGHTS WERE ROUNDED OFF TO THE NEAREST ONE-TENTH OUNCE:
(A) SIX 65% CALCIUM HYPOCHLORITE TABLETS = APPROXIMATELY I OUNCE
(B) THREE HEAPING TABLESPOONS OF 65% CALCIUM HYPOCHLORITE =: APPROXIMATELY 1 OUNCE
FOR COMPOUNDS WITH CHLORINE CONCENTRATIONS DIFFERENT FROM THOSE IN THE TABLES, USE EQUATION 1 OR 2 (REFER TO TEXT) TO DETERMINE THE AMOUNT OF COMPOUND REQUIRED.

Placement of the Disinfectant Solution

For drilled or driven wells, pour the disinfectant solution into the top of the well, being sure that the casing walls are wetted completely. In order to thoroughly distribute the disinfectant, the well should be pumped, recirculating the pumped water back into the well for at least 15 minutes. Recirculation should be accomplished by connecting a hose to a faucet on the discharge side of the pressure tank and running it back to the well. If a pump has not been installed and a temporary pump is not available, a bailer or plunger should be used to mix the disinfectant throughout the well.

After the disinfectant has been circulated throughout the well and the pressure tank, all the household faucets should be turned on, letting the water run until the odor of chlorine is detected. Then turn off the faucets and seal the top of the well.

For dug wells, the disinfectant solution should be splashed around the lining or wall of the well, being sure that the solution comes in contact with all parts of the well. The top of the well should then be sealed and the well should be pumped until the odor of chlorine is detected in the discharge.

Retention Time for the Disinfectant Solution

The disinfectant solution should remain undisturbed in the well and, if connected, in the distribution system for a minimum of two hours.

Flushing the System

Pump the well and flush all traces of chlorine from the distribution system, being sure to turn on all the household faucets. If the water supply system ultimately discharges to a septic tank, care should be taken to flush the distribution system slowly, keeping the faucets turned on low. This prevents the septic system from becoming overloaded.

EFFECTIVENESS OF THE DISINFECTION PROCEDURE

After all the chlorine has been flushed from the water supply system, the local Board of Health should require that a water sample be collected, and submitted to a state certified laboratory for a bacteriological analysis that detects the presence of coliform bacteria. If the results of the analysis indicate more than one coliform bacterium per 100 mls of water, the well should not be put into service and the system should be disinfected again using a higher concentration of chlorine or a longer retention time. After disinfection, the water should be sampled again and analyzed to ensure that the standard for coliform bacteria is not exceeded. For new wells, the local Board of Health may choose to require testing for additional parameters (refer to the following section entitled, "Water Quality and Water Testing").

Ineffective disinfection may be related to the chlorine concentration of the disinfectant, the pH or turbidity of the water, or the retention time of the disinfectant solution. For water with a high pH, a higher initial chlorine concentration is required to obtain the same level of disinfection achieved with less chlorine in low-pH water. This is because the hypochlorous ions, which function as the bactericide, are more effectively neutralized as the pH increases. The effectiveness of the disinfectant also decreases as turbidity increases. Retention time of the disinfectant solution in the system is also critical to the effectiveness of the disinfection procedure; the disinfectant must remain long enough to kill the bacteria.

WATER QUALITY AND WATER TESTING

This section consists of the following subsections:

- Regional Water Quality Differences
- Sources of Contamination
- Parameters and Testing Frequency
- Recommended Use of Certified Laboratories
- Recommended Water Quality Report
- Water Supply Certificate

REGIONAL WATER QUALITY DIFFERENCES

The geologic materials from which groundwater is pumped differ regionally within Massachusetts and, therefore, natural water quality differences can be expected. The four principal types of geologic materials (aquifers) tapped by private wells are; (1) unconsolidated, glacially derived stratified drift deposits consisting of layered sand and gravel with some silt, (2) crystalline bedrock consisting primarily of granite, schist, and gneiss, (3) sedimentary bedrock consisting of red sandstone, shale, conglomerate with interbedded basaltic lava (traprock), and (4) carbonate rock consisting of limestone, dolomite, and marble with interbedded schist and quartzite. The geographic distribution of these aquifers is illustrated in Figure 15.

The homeowner and the local Board of Health should be aware of the naturally occurring water quality characteristics common in the principal types of aquifers.

Stratified drift aquifers occur in scattered river valleys throughout Massachusetts and form a continuous layer over the bedrock on Cape Cod, Nantucket, and most of Martha's Vineyard. Wells completed in stratified drift aquifers are commonly less than 100 feet deep and yield water that is generally slightly acidic (pH less than 7.0), soft (low calcium carbonate concentration), contains low concentrations of dissolved solids, and is corrosive to metal and cement pipe. Stratified drift aquifers in Berkshire County, however, yield water with characteristics similar to those described for the carbonate rock aquifer (below). Some stratified drift aquifers yield water containing high concentrations of iron and manganese which cause taste, color, and staining problems, and may cause decreased well efficiency due to encrustation of the well screen. In addition, wells which initially yield water with low concentrations of iron and manganese may, with time, yield water with higher concentrations of these metals and may exhibit a decrease in well efficiency. In coastal areas, salt water intrusion may cause a well to yield unpotable water.

Crystalline bedrock aquifers are present throughout a large portion of Massachusetts. However, these aquifers are not utilized on Cape Cod, Martha's Vineyard and Nantucket because in these areas the bedrock occurs at great depth, contains saline water, or is overlain by more accessible stratified drift deposits. Wells completed in crystalline bedrock aquifers are commonly 100-400 feet deep and generally yield moderately hard water with low concentrations of dissolved solids.

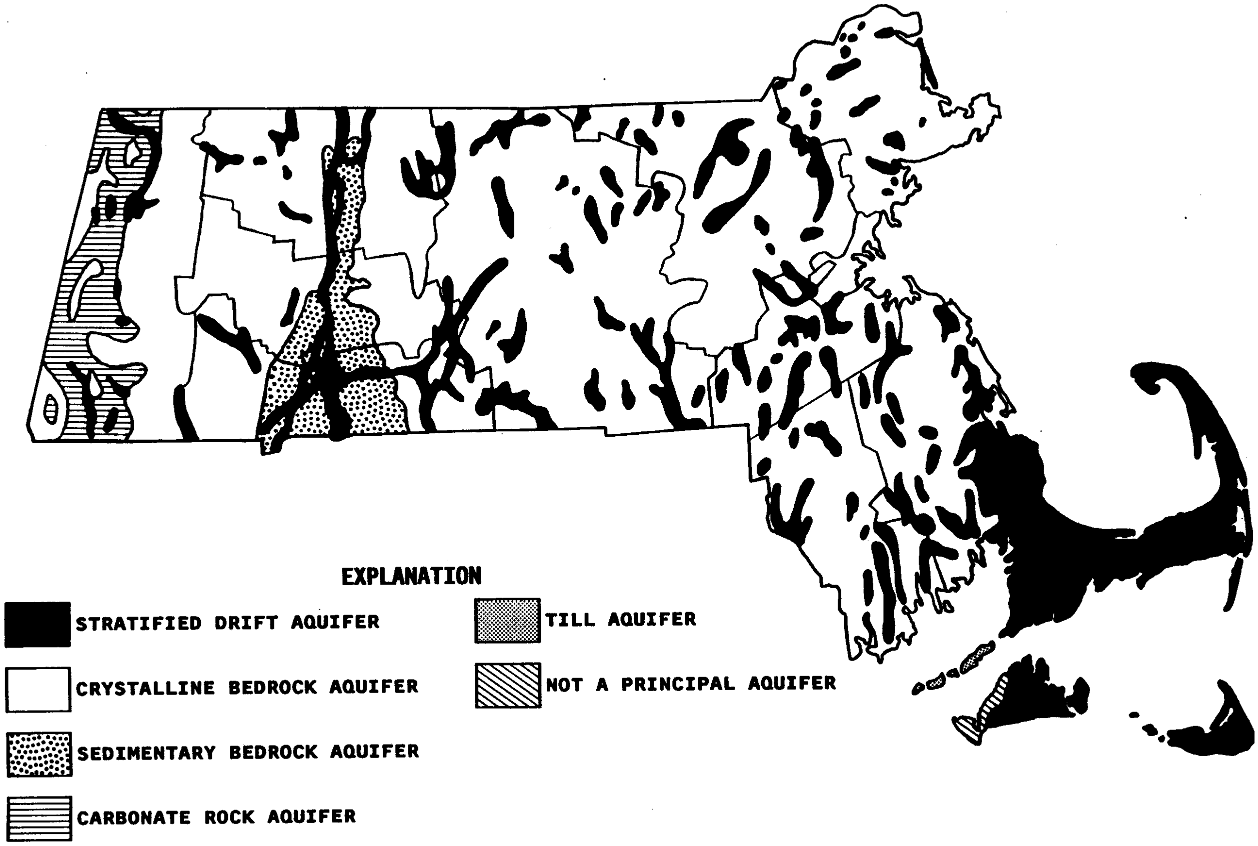

Figure 15: Principal Aquifers in Massachusetts (after Frimpter, 1985).

Variations in the composition of crystalline bedrock aquifers, however, cause local variations in water quality. High iron concentrations, often requiring treatment, occur in areas where the bedrock consists of "rusty" schist or gneiss which contain small amounts of the minerals pyrite or pyrrohotite or an abundance of ferromagnesian minerals. High arsenic concentrations have been found in water from a few wells completed in crystalline bedrock aquifers in Hampden, Worcester, and Middlesex counties. High levels of naturally occurring uranium, radon, arsenic and selenium have been found in water from a well in Tyngsborough which was completed in a crystalline bedrock aquifer known as the Berwick Formation. High levels of these parameters do not occur uniformly throughout the Berwick Formation but may be found in localized areas. Because the Berwick Formation underlies Tyngsborough, Haverhill, and Methuen, and parts of Dracut, Dunstable, East Pepperell, Groton, Lowell, North Chelmsford, and Westford, the aforementioned parameters should be considered when testing wells in these towns.

Sedimentary bedrock aquifers exist in the Connecticut River valley. Wells completed in these aquifers are commonly 100-250 feet deep and yield water which often contains relatively high concentrations of sulfate, sodium and fluoride. The upper 200 feet of the aquifer generally produces moderately hard water with moderate levels of dissolved solids while water from deeper parts of the aquifer is often hard and commonly contains high concentrations of dissolved solids. High concentrations of sulfate and/or dissolved solids typically cause the water to taste bitter. Extreme hardness prevents soaps and detergents from forming suds and can cause scaling (encrustation) of plumbing. Water quality may be affected locally by ore deposits that contain copper, lead, and zinc sulfides, fluorite, and uranium-bearing minerals.

Carbonate rock aquifers are present in Berkshire County. Wells completed in these aquifers are commonly 100-300 feet deep. The aquifer yields hard water with relatively high concentrations of calcium carbonate. Extreme hardness prevents soaps and detergents from forming suds and can cause scaling (encrustation) of plumbing.

SOURCES OF CONTAMINATION

Unfortunately, all of the aquifers discussed can be adversely affected by waterborne contaminants generated by industry; commercial and agricultural interests; improper or poorly situated waste disposal; and sanitary wastewater disposal. Public and private wells alike have been contaminated by petroleum products, cleaning solvents, sewage, road salt, and pesticides.

The "Land Use/Public-Supply Well Pollution Potential Matrix" (Figure 16) is a guide for assessing the potential water quality impacts various land uses may have on groundwater systems. Although intended for use when assessing risk to public supply wells, the potential water quality implications are still applicable to private wells.

PARAMETERS AND TESTING FREQUENCY

Table 8 is provided to assist local Boards of Health in evaluating the quality of domestic water supplies and provide guidance regarding testing frequencies for various parameters. These recommended concentration limits have been determined by either the U.S. Environmental Protection Agency or the DEP Office of Research or Standards (ORS) to be protection of human health.

Table 9 is a list of chemicals that are generally not recommended for private well monitoring unless a contamination problem has been identified by the Board of Health, the Department of Public Health, or DEP. For information on the derivation of the recommended concentration limits, and general information on the health effects of water contaminants, please contact ORS at (617) 292-5570.The parameters listed in Table 10 are not based on health considerations, but rather on the effect they may have on taste, color and/or odor of drinking water.

Table 11 presents parameters which along with nitrate, sodium, and are good indicators pollutants that might also contain the types of compounds and chemicals noted in Tables 8 and 9. For example, high concentrations of nitrate, chloride and ammonia in drinking water might indicate that the well is drawing in septic effluent. Since septic effluent frequently contains volatile organic compounds, it would be advisable to have the source of drinking water analyzed for volatile organics. High concentrations of iron, manganese, total dissolved solids, nitrogen (as ammonia or nitrate) and extreme hardness are typical indicators of landfill leachate. High concentrations of these parameters in domestic drinking water should trigger an expanded analysis to include all of the parameters in Tables 8, and 9 because many of them are also found in landfill leachate.

Boards of Health should consider several things when deciding what testing program is most appropriate for their town. Previously discussed naturally occurring contaminants and past and present land use are of primary importance. Some land uses that have a potential to adversely impact water quality that should be considered include:

- storage or disposal of
  - herbicides
  - pesticides,
  - fertilizers
  - hazardous materials
- subsurface waste disposal.

Land Use Considerations	Acids	Bases	Chloride	Fluoride	Iron/Manganese (Fe/Mn)	Metals (except Fe & Mn)	Nitrate[1]	Pathogens (Virus/Bacteria)	Pesticides/Herbicides	Petroleum Products	Phenols	Radioactivity	Sodium	Solvents	Sulfate	Surfactants (Detergents)	Overall Threat to Public Water Supply[3]
Overall Threat to Public Health	L-M	L-M	L	L	L	H	M	L	H	H	H	H	L	H	L	L	
Mobility	M	L	H	H	M	L H	H	L	L H	M	M	L H	H	H	H	H	
Natural Background	■		■	■	■	■						■	■		■		
Land Use Categories																	
Agriculture/Golf Courses							■		■								M
Airports						■			■	■				■		■	M-H
Asphalt Plants										■							L-M
Beauty Parlors[2]		■				■								■		■	L[2]
Boat Yards/Builders						■				■	■			■			L
Car Washes			■			■				■			■	■		■	L
Cemeteries									■								L
Chemical Manufacture	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	H
Clandestine Dumping	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		H
Dry Cleaning														■			H
Furniture Stripping and Painting	■	■				■								■			M
Hazardous Materials Storage and Transfer	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	H
Industrial Lagoons and Pits	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	H
Jewelry and Metal Plating	■	■		■	■	■				■			■	■		■	M
Junkyards	■				■	■				■				■	■		L
Landfills	■		■		■	■	■	■	■	■	■	■	■	■	■		H
Laundromats								■						■		■	L-M
Machine Shops/Metal Working	■	■				■				■				■		■	H
Municipal Wastewater/Sewer Lines					■	■	■	■					■	■		■	H
Photography Labs/Printers	■	■				■								■		■	L-M
Railroad Tracks and Yards Maintenance Stations	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	M
Research Labs/Universities/Hospitals	■	■		■	■	■	■	■	■	■	■	■		■		■	L-M
Road and Maintenance Depots			■						■	■			■	■			M
Sand and Gravel Mining/Washing										■				■			L
Septage Lagoons and Sludge			■		■	■	■	■					■	■		■	H
Septic Systems, Cesspools and Water Softeners			■		■	■	■	■	■				■	■		■	H
Stables, Feedlots, Kennels, Piggeries, Manure Pits							■	■					■				M-H
Stormwater Drains/Retention Basins			■			■		■	■	■			■	■			L-M
Stump Dumps					■	■	■				■		■				L
Underground Storage Tanks									■	■				■			H
Vehicular Services						■				■				■		■	H
Wood Preserving						■				■	■			■	■	■	L

■ The contaminant(s) released from this land-use category *may render* groundwater at a public-supply well undrinkable in accordance with federal and state maximum contaminant levels.

☐ This land use category is not generally associated with the release of the particular contaminant in quantities that would render the groundwater at a public-supply well undrinkable. However, the contaminant may be associated with a particular activity.

L = Low Threat M = Medium Threat H = High Threat

This Matrix is based on a literature review and the combined field experience of the Cape Cod Aquifer Management Project (CCAMP). **THIS MATRIX SHOULD BE USED AS A GUIDE AND HANDY REFERENCE.** It is not a substitute for looking at a particular land use in detail. There will always be the potential for a business to use an unusual process using chemicals not normally associated with that business. The land-use categories included in the Matrix and *Guide to Contamination Sources for Wellhead Protection* are those that might be found in the primary recharge area of a public-supply well in Massachusetts. This Matrix may be misleading or erroneous if applied to low-yield private wells.

1 Nitrate has a cumulative impact on groundwater quality. No one category is responsible for the release of nitrate. A variety of land use categories release nitrate. These include animal feedlots, landfills, septic systems, septage lagoons, municipal wastewater and agricultural activities including turf maintenance.

2 There are no known instances of beauty parlors contaminating well water in Massachusetts. More research is needed to determine the severity of a threat to groundwater from this land use category.

3 Refer to *Guide to Contamination Sources for Wellhead Protection*, pp 1 2

Table 8
Recommended Analytes, Concentration Limits and Monitoring Frequency for Private Wells

Parameter	Recommended Concentration Limit	Recommended Sampling Frequency
Inorganic Compounds		Monitor initially for all compounds and then once every ten years if no detects, or as otherwise determined by the local Board of Health.
Antimony	0.006 mg/l	
Arsenic	0.01 mg/l	
Asbestos	7 million fibers/l	
Barium	2 mg/l	
Beryllium	0.004 mg/l	
Cadmium	0.005 mg/l	
Chromium (total)	0.1 mg/l	
Cyanide	0.2 mg/l	
Fluoride	4 mg/l	
Lead (action level)	0.015 mg/l	
Copper (action level)	1.3 mg/l	
Mercury	0.002 mg/l	
Nitrate (N)	10 mg/l	Note: Nitrate and Nitrite should be monitored once every year.
Nitrite (N)	1 mg/l	
Total Nitrate & Nitrite (N)	10 mg/l	
Selenium	0.05 mg/l	
Thallium	0.002 mg/l	
Synthetic Organic Compounds		
Alachlor	0.002 mg/l	Perform a monitor screen initially using analytical method 505 or 508 and then once every ten years if no detects, or as specified by the Local Board of Health. Owners of wells in agricultural areas are encouraged to conduct more frequent testing.
Atrazine	0.003 mg/l	
Benzo(a)pyrene	0.0002 mg/l	
Carbofuran	0.04 mg/l	
Chlordane	0.002 mg/l	
Dalapon	0.2 mg/l	
Di(2-ethylhexyl)adipate	0.4 mg/l	
Di(2-ethylhexyl) phthalate	0.006 mg/l	Monitoring for the following pesticides may also be recommended by the Board of Health on a case by case basis if the area is vulnerable is vulnerable to this type of contamination.
Dinoseb	0.007 mg/l	
Diquat	0.02 mg/l	
Dibromochloropropane (DBCP)	0.0002 mg/l	
2,4-D	0.07 mg/l	
Endothall	0.1 mg/l	Aldrin
Endrin	0.002 mg/l	Aldicarb
Ethylene Dibromide (EDB)	0.00002 mg/l	Aldicarb sulfoxide
Glyphosate	0.7 mg/l	Aldicarb sulfone
Heptachlor	0.0004 mg/l	Butachlor
Heptachlor epoxide	0.0002 mg/l	Carbaryl
Hexachlorobenzene	0.001 mg/l	Dicamba
Hexachlorocyclopentadiene	0.05 mg/l	Dieldrin
Lindane	0.0002 mg/l	3-Hydroxycarbofuran
Methoxychlor	0.04 mg/l	Methomyl
Oxamyl(Vydate)	0.2 mg/l	Metolachlor
Polychlorinated biphenyls (PCBs)	0.0005 mg/l	Metribuzin
Pentachlorophenol	0.001 mg/l	Propachlor
Picloram	0.5 mg/l	
Simazine	0.004 mg/l	
2,3,7,8-TCDD (Dioxin)	$3x10^{-8}$ mg/l	
Toxaphene	0.003 mg/l	
2,4,5-TP (Silvex)	0.05 mg/l	

concentrations are given in mg/l; to convert to ug/l multiply concentration in mg/l by 1000

Table 8 (continued)
Recommended Analytes, Concentration Limits and Monitoring Frequency for Private Wells

Parameter	Recommended Concentration Limit	Recommended Sampling Frequency
Coliform Bacteria	Positive sample	Monitor once every year , or as otherwise specified by the local Board of Health
Volatile Organic Compounds		
Benzene	0.005 mg/l	Monitor initially for VOCs and then once every 10 years if no detects, or as otherwise determined by the local Board of Health. Owners of wells in industrial or densely developed residential areas are encouraged to conduct more frequent testing.
Carbon Tetrachloride	0.005 mg/l	
Dichloromethane	0.005 mg/l	
o-Dichlorobenzene	0.6 mg/l	
p-Dichlorobenzene	0.005 mg/l	
1,2-Dichloroethane	0.005 mg/l	
cis-1,2-Dichloroethylene	0.07 mg/l	Initial monitoring for the following VOCs is also recommended and can be identified during the same analysis performed for the VOCs listed to the left.
trans-1,2-Dichloroethylene	0.1 mg/l	
1,1-Dichloroethylene	0.007 mg/l	
1,2-Dichloropropane	0.005 mg/l	
Ethylbenzene	0.7 mg/l	
Methyl Tertiary Butyl Ether(MTBE)	0.07 mg/l	Bromobenzene; 1,3 Dichloropropane
Monochlorobenzene	0.1 mg/l	Bromodichloromethane; 2,2 Dichloropropane
Styrene	0.1 mg/l	Bromoform; 1,1 Dichloropropene
Tetrachlorothylene (PCE)	0.005 mg/l	Bromomethane; 1,3 Dichloropropene
Toluene	1 mg/l	n-Butylbenzene; Fluorotrichloromethane
Trichloroethylene (TCE)	0.005 mg/l	sec-Butylbenzene; Hexachlorobutadiene
1,1,1-Trichloroethane (1,1, 1-TCA)	0.2 mg/l	tert-Butylbenzene; Isopropylbenzene
1,2,4-Trichlorobenzene	0.07 mg/l	Chloroethane; p-Isopropyltoluene
1,1,2-Trichloroethane	0.005 mg/l	Chlordibromomethane; Napthalene
Vinyl Chloride (VC)	0.002 mg/l	Chloroform; n-Propylbenzene
Xylenes(total)	10 mg/l	Chloromethane; 1,1,1,2-Tetrachloroethane
		o-Chlorotoluene; 1,1,2,2-Tetrachloroethane
		p-Dichlorotoluene; 1,2,3-Trichlorobenzene
		m-Dichlorobenzene; 1,2,3-Trichloropropane
		Dibromomethane; 1,2,4- Trimethylbenzene
		Dichlorodifluoromethane; 1,3,5-Trimethylbenzene
		1,1-Dichloroethane
Radionuclides		
Gross Alpha Activity	15 pCi/l	Monitor for radionuclides initially. If detected contact the Local Board of Health for more information.
Radium –226 & 228	5 pCi/l	
Uranium	20 ug/l	Note: Also monitor initially for Radon 222 Radon is commonly found in Massachusetts groundwaters as a decay product of uranium in the underlying soil or bedrock. If detected, contact your local Board of Health for more information.

Table 9
Recommended Analytes, Concentration Limits and Monitoring Frequency for Private Wells

Parameter	**Recommended Concentration Limit**	**Recommended Sampling Frequency** ***These parameters are generally not recommended for private well monitoring,*** *unless a problem has been identified by the Board of Health, the Department of Public Health, or DEP.*
Acetone	3 mg/l	
Bromomethane	0.01 mg/l	
Chloroform	0.005 mg/l	
Dichlorodifluoromethane	1.4 mg/l	
1,1-Dichloroethane	0.07 mg/l	
1,3-Dichloropropene	0.0005 mg/l	
1,4-Dioxane	0.05 mg/l	
Ethylene Glycol	14 mg/l	
Methyl Ethyl Ketone	0.35 mg/l	
Methyl Isobutyl Ketone	0.35 mg/l	
Metolachlor	0.1 mg/l	
Naphthalene	0.140 mg/l	
Nickel	0.1 mg/l	
Radon-222	10,000 pCi/l	
Sodium	20 mg/l	The recommended concentration for Sodium is based on an eight (8) ounce serving.
Tetrahydrofuran	1.3 mg/l	
Trichlorotrifluoroethane (Freon113)	210 mg/l	
Uranium	20 ug/l	

Table 10
Recommended Analytes, Concentration Limits and Monitoring Frequency for Private Wells

Parameter	**Recommended Concentration Limit**	**Recommended Sampling Frequency**
Aluminum	0.05 to 0.2mg/l	These parameters are generally recommended for initial monitoring and then once every 10 years or as otherwise determined by the Local Board of Health.
Chloride	250 mg/l	
Color	15 color units	
Copper	1 mg/l	
Fluoride	2 mg/l	
Foaming Agents	0.5 mg/l	
Iron	0.3 mg/l	
Manganese	0.05 mg/l	
Odor	3 TON	TON: Threshold Odor Number
pH	6.5-8.5	
Silver	0.10 mg/l	
Sulfate	250 mg/l	
Total Dissolved Solids	500 mg/l	
Zinc	5 mg/l	

Table 11
Indicator Parameters

Parameter	Recommended Upper Limit	Recommended Lower Limit
alkalinity	100mg/l	30 mg/l
calcium	150 mg/l	50 mg/l
chloride	250 mg/l	N/A/
color	15 color units	N/A
copper	1 mg/l	N/A
hardness	200 mg/l	50 mg/l
iron	0.3 mg/l	N/A
magnesium	Relative scale	N/A
manganese	0.05 mg/l	N/A
nitrogen (as ammonia)	0.1 mg/l	0.015 mg/l
nitrogen (as nitrite)	1 mg/l	N/A
odor	3 TON	N/A
pH	8.5	6.5
potassium	Relative scale	N/A
sediment	visual observation	N/A
sulfate	250 mg/l	N/A
total dissolved solids	500 mg/l	N/A

Although, private well contamination is often identified through detection of an unpleasant or unnatural taste or odor, consumers should keep in mind that harmful concentrations of several contaminants do not impart a noticeable taste or odor to the water. It is prudent to have the well water sampled periodically and tested by a certified laboratory. The following sampling scheme is suggested:

(1) After disinfection and prior to being put into service, new domestic water supply wells should be sampled and the sample should be analyzed for coliform, nitrate, turbidity, the volatile organic compounds listed in Table 8, sodium, and all of the parameters listed in Table 10. Samples taken from wells completed in crystalline bedrock should also be analyzed for radon, arsenic, and selenium. Additionally, in areas where current or historical land use includes agriculture, the sample should be analyzed for pesticides, herbicides, and arsenic.

(2) Every three years, homeowners with wells located proximal to land uses and/or intensive residential developments that are potentially impacting groundwater quality should have their water analyzed for coliform, nitrate, turbidity, the volatile organic compounds listed in Table 8, sodium, and all of the parameters listed in Table 10.

(3) Every three years, homeowners who are located in relatively rural areas and who have had their water analyzed for the parameters indicated in (1), above, should have their water analyzed for coliform, nitrate, and all of the parameters listed in Table 10. In areas where current or historical land use includes agriculture, analysis for pesticides, herbicides, and arsenic is also recommended.

(4) Persons intending to purchase a home served by a domestic well should request water quality information and/or have the well sampled and tested as recommended in (1), above.

All water quality analyses should be conducted utilizing methods approved by the U. S. Environmental Agency for analyzing drinking water (500 Series Methods, U.S.EPA, 1988) and **not** methods used for analyzing wastewater (600 Series Methods, 49 FR 28).

Existence of any of the parameters noted in Table 9 should be brought to the attention of the local Board of Health. If any of the limits noted in Tables 8, 9, and 11 are exceeded, a second water quality test should be conducted to confirm the results of the first analysis. If the limit is exceeded in the second analysis, treatment may be necessary and the local Board of Health should be notified.

Exceedance of the recommended limit for sodium noted in Table 8 is primarily of concern to persons on low sodium diets. If road salt is suspected as the source of high sodium levels, the well owner or Board of Health should contact the Massachusetts Highway Department (Research and Materials Section).

RECOMMENDED USE OF CERTIFIED LABORATORIES

All water quality analyses should be performed by a laboratory that is certified by the State for the specific analysis required. The Commonwealth of Massachusetts has an ongoing laboratory certification program administered by the Lawrence Experiment Station. Through this program laboratories are certified to perform specific analyses. It is important to note, however, that a laboratory that is certified for one type of analysis may not be certified for another type of analysis. In addition, since the certification process is ongoing, a laboratory may, at any time, lose its certification for a particular analysis. Thus, prior to contracting a laboratory for a particular analysis, it should be verified that the laboratory has current certification by the State to perform such an analysis. Most laboratories are certified to perform analyses for the indicator parameters listed in Table 10 and many are certified to perform analyses for the parameters listed in Tables 8 and 9. Even if the lab is certified, it is advisable to review the data for accuracy.

RECOMMENDED WATER QUALITY REPORT

It is recommended that the local Board of Health require the well owner to submit to the Board a Water Quality Report anytime a private water supply is tested. The report should include:

(1) who performed the sampling (i.e., BOH member, BOH agent, lab personnel, well owner, well owner's agent)

(2) where in the system the sample was obtained (point-of-use or point-of-entry) and, if sampled at the point-of-use, whether or not the system was flushed prior to sampling

(3) type of water treatment used (chemical or special device), if applicable

(4) how long after sampling the sample was delivered to the laboratory

(5) a copy of the laboratory's test results

Results that indicate no contamination are as important as those that indicate water quality problems because these results provide background data in case of future contamination. A complete record of all testing results is also useful when designing local water quality testing programs.

WATER SUPPLY CERTIFICATE

The issuance of a Water Supply Certificate by the Board of Health certifies that the private well may be used as a drinking water supply. A Water Supply Certificate must be issued for the use of a private well prior to the issuance of an occupancy permit for an existing structure or prior to the issuance of a building permit for new construction which is to be served by the well.

The following should be submitted to the Board of Health in order to obtain a Water Supply Certificate;

(1) a well construction permit
(2) a copy of the Water Well Completion Report as required by the Division of Water Resources
(3) a copy of the Pumping Test Report
(4) a copy of the Water Quality Report

Upon the receipt and review of the above documents, the Board of Health may;

(1) Issue a Water Supply Certificate.
(2) Deny the applicant a Water Supply Certificate and specify the reasons for the denial.
(3) Issue a conditional Water Supply Certificate with those conditions which the Board deems necessary to ensure fitness, purity and quantity of the water derived from that private well. The conditions may include, but are not be limited to requiring treatment or testing of the water •

WELL MAINTENANCE, REHABILITATION, AND ALTERATION

This section consists of the following subsections;

- General Considerations
- Well Maintenance
- Well Rehabilitation
- Well Alteration

GENERAL CONSIDERATIONS

All materials and construction practices used in the maintenance, repair, or alteration of any well should be the same as those required for the construction of a new well. All maintenance, repair, and reconstruction work should be done only by a registered well driller, or by a licensed plumber or electrician.

Upon completion of any alteration of a well, or maintenance or repair work done on a well or its pumping equipment, the contractor should disinfect the well, the pumping equipment and the distribution system before the well is returned to service. Appropriate disinfection procedures are discussed in the section entitled "Disinfection".

WELL MAINTENANCE

This subsection consists of the following parts;

- General Maintenance
- Temporary Abandonment

General Maintenance

The well owner should be responsible for;

(1) maintaining the well in a sanitary condition

(2) maintaining the well in a manner that prevents surface water or contaminants from entering the well

(3) maintaining the well in a manner that conserves ground-water resources

(4) maintaining the well so that it is accessible for rehabilitation and repairs

(5) ensuring that an abandoned well is properly plugged

Valves and casing of artesian wells should be maintained in a condition that permits the flow of water to be stopped and prevents leakage from the confined aquifer. The well owner should adjust the valves so that the quantity of water flowing from the well is adequate for ordinary use and no excess water is being wasted. The flow of water should be shut off any time the water is not being used beneficially. The access port or pressure gauge should be maintained in a condition that permits the level of the water surface or the artesian pressure to be measured at any time.

Temporary Abandonment

When a well is not abandoned, but is out of use for an extended period of time, it should be the owner's responsibility to properly maintain the well and to prevent the development of defects which may facilitate the impairment of water quality in the well or in the water bearing formations penetrated by the well Until a well is permanently abandoned by plugging procedures, as described in the following section entitled "Decommissioning Abandoned Wells, Test Holes, and Dry or Inadequate Borings", all provisions for protection of the water from contamination and for maintaining sanitary conditions around the well should be carried out to the same extent as though the well were in routine use.

To temporarily abandon a well, the top of the well casing should be sealed with a watertight threaded cap or with a steel plate welded watertight to the top of the casing. If the pump or well seal is water tight, the pump may be left in place. A well that has, after extended use, been temporarily abandoned for 3 years should be permanently abandoned.

WELL REHABILITATION

This subsection consists of the following parts;

- General Considerations
- Major Causes of Deteriorating Well Performance

GENERAL CONSIDERATIONS

Well rehabilitation is defined as restoring a well to its most efficient condition by various methods of treatment or reconstruction. The necessity for well rehabilitation depends on the effectiveness of the maintenance program and how faithfully it has been followed. In some cases, a major reconstruction of the well may be necessary, such as replacing the screen or lining a portion of the casing. Timely maintenance designed to overcome specific problems can sustain well performance, thereby prolonging well life.

It is important to take note of any changes in the operating characteristics of the well and pump, because both can deteriorate to the point where rehabilitation is difficult, if not impossible. Experience indicates that if the specific capacity of a well declines by 25 percent, it is time to initiate rehabilitation procedures. Further neglect significantly increases maintenance costs.

Major Causes of Deteriorating Well Performance

(1) Incrustation and Biofouling of the Screen and Surrounding Formation
(2) Physical Plugging of the Screen and Surrounding Formation *
(3) Onset of Sand Pumping
(4) Structural Collapse of the Well Casing or Screen

Incrustation and Biofouling of the Screen and Surrounding Formation

Well yield may be reduced by chemical incrustation or biofouling of the well screen and the formation materials around the intake portion of the well. Water quality chiefly determines the occurrence of incrustation. The surface of the screen itself may also play a part in regulating the rate at which incrustation occurs. Screens constructed of rough-surface metal may be more prone to incrustation. The kind and amount of dissolved minerals and gases in natural waters determine their tendency to deposit mineral matter as incrustation. The incrustation often forms a hard, brittle, cement like deposit similar to the scale found in water pipes. Under different conditions, however, it may be a soft, paste like sludge of a gelatinous material. The major forms of incrustation include;

(1) incrustation from precipitation of calcium and magnesium carbonates or their sulfates;

(2) incrustation from precipitation of iron and manganese compounds, primarily their hydroxides or hydrated oxides;

(3) plugging caused by slime producing iron bacteria or other slime-forming organisms (biofouling).

Prevention and Treatment of Incrustation Problems

For most wells where incrusting materials cannot be removed before reaching the well, several actions can be taken to delay incrustation and make it a less serious problem. First, the well screen should be designed to have the maximum possible inlet area to reduce the flow velocity to a minimum through the screen openings. Second, the well should be developed thoroughly. Third, the pumping rate may be reduced and the pumping period increased, thereby decreasing entrance velocities.

Chemical incrustation can best be removed by treating the well with a strong acid solution that chemically dissolves the incrusting materials so they can be pumped from the well. The acids most commonly used in well rehabilitation are hydrochloric (HCL), which is prepared commercially under the name muriatic acid, and is one of the most effective acids for mineral scale removal; sulfamic (H_3NO_3S), a dry white, granular material that produces a strong acid when mixed with water; and hydroxyacetic ($C_2H_4O_3$), also known as glycolic acid, which is a liquid organic acid available commercially in 70-percent concentrations.

Provisions should be made to neutralize acids and other chemicals used to rehabilitate a well. For example, acid solutions should be pumped to waste through agricultural lime or other suitable material.

Great care should be taken in placing liquid acid into a well. Only experienced personnel with specialized equipment should attempt to use it in rehabilitating a well. When using any liquid acid, the following precautions should be followed;

(1) wear protective rubber clothing and goggles

(2) a breathing respirator should be used by all personnel handling the acid and by persons near the well

(3) all mixing tanks, chemical pumps, and piping (tremie pipes) should be constructed of plastic or black iron to minimize reaction to acid

(4) a large quantity of water, or a water tank with a mixture of sodium bicarbonate, should be available in the event that an accident occurs

(5) proper ventilation must be maintained because the fumes released from the well treatment are lethal

Liquid acid should be introduced into the well through a small diameter pipe. If the screen is more than 5 feet long, enough acid should be added to fill the lower 5 feet of screen. Then the pipe should be raised and the next 5 feet of screen filled with acid, continuing in this manner until the entire screen is full.

After the acid is placed in the well (or the pellets dissolve), a volume of water equal to that standing in the well screen should be poured into the well to force the acid solution through the screen into the formation. Some form of mechanical agitation, such as surging, should be employed while the acid is in the well to help break up the incrustation and improve the overall efficiency of the process. This step is particularly important because it exposes the incrustant to the acid, thereby assuring maximum removal. The use of surge blocks or jetting tools are effective methods of agitating the well. The agitation time will depend on the amount of incrustant in the well

Another method available for the removal of incrustants is by mechanical means. This method is useful in either the preparation for acid treatment or as a primary method of removing incrustants. Wire brushing or other means of mechanical scraping can remove incrustants that have been deposited on the inside of the well screen. The loosened material is then removed from the well by bailing, airlift pumping, or other means. Removal of these incrustants minimizes the quantity of acid that must be used in any subsequent acid treatment, enhances the effectiveness of this treatment, and reduces the time required for the acidizing process.

Well Failure Caused by Physical Plugging of the Screen and Surrounding Formation

It can be expected that over time, almost all screened wells will experience some loss in specific capacity. This loss may be partially due to the slow movement of fine formation particles into the area around the screen. Many of these particles may partially plug the screen itself, depending on the type of screen slot opening, or even erode the slot openings under certain conditions. In summation, the movement of small particles reduces the yield, increases the drawdown, and may damage the screen.

The movement of these fine particles may be the result of a number of factors including (1) improper screen placement, poor slot selection, or inaccurate aquifer sampling techniques, (2) insufficient or improper development before the well was placed in service, (3) removal of cement holding the sand grains together around the well screen, (4) corrosion of the screen or casing, (5) increase in the pumping rate beyond the designed capacity, and (6) excessive pump cycling, although this may pertain more to high yield wells than small yield private wells.

Thorough development of the well during its completion can greatly decrease the movement of sediment into the formation around the well screen. The application of an appropriate development technique for a sufficient length of time will stabilize the formation material so that subsequent pump cycling and higher discharge rates will not result in sediment movement.

Onset of Sand Pumping

Some wells always pump sand, a condition attributable to poor well design or inadequate development. Other wells may begin to pump sand after months or years of service. Localized corrosion of the well screen or casing, or incrustation on only a portion of the screen, can produce higher velocities through either the corroded opening or the nonincrusted areas of the screen. Thus corrosion and incrustation are major factors in sand pumping problems that develop over time. In some well-cemented sandstones, removal of the cement by water passing into the well can weaken the sandstone to the point where sand particles begin to move into the well.

Structural Collapse of the Well Casing or Screen

Corrosion is defined as chemical action on a material exerted by outside factors, which causes destruction of the material. Corrosion of the well screen, casing or pumping equipment can severely limit the useful life of the well. Due to either the corrosive or incrustive nature of most natural waters, the effect will be a matter of degree and nature. The rate at which corrosion takes place depends on several factors such as the acidity of the groundwater, presence or absence of oxidizing agents, movement of the water over areas being corroded, electrolytic effects, formation of films or protective deposits and temperature of the corrosive reactions.

WELL ALTERATION

This subsection consists of the following parts;

- Extension of Existing Casing
- Reconstructing Dug Type Wells

Extension of Existing Casing

An existing casing can be extended above ground by welding a casing extension to the existing casing. Another method is to carefully telescope a section of larger casing over the existing one for a length of 5 feet. The casing should extend 18 inches above the surrounding ground and the inside diameter of the addition should be 3 inches greater than the inside diameter of the existing well casing. The annular space between the casings should be made equal all around and then filled with cement grout. The space around the outside of the casing extension should be filled with tamped concrete. Regardless of the method used to extend the well casing above ground, it is necessary to provide a sanitary well seal. The well should then be disinfected as previously described in the section entitled “Disinfection".

Reconstructing Dug Type Wells

A drilled type well may be constructed through an existing dug well in accordance with the following procedure;

(1) Remove any sediment or debris from the bottom of the dugwell.

(2) Disinfect the existing dug well with a chlorine solution containing a chlorine concentration of 100 mg/l.

(3) Drill through the bottom of the dug well following the appropriate procedures for drilled wells.

(4) "Dug and drilled" type wells should be effectively protected against the entrance of surface water by extending the casing of the drilled part of the well to an elevation of at least 12 inches above the established ground surface and filling the dug part of the well with neat cement grout or sand cement grout. Removing the top 7 or 8 feet of curbing creates a good soil to soil bond.

DECOMMISIONING ABANDONED WELLS, TEST HOLES, AND DRY OR INADEQUATE BORINGS

This section consists of the following subsections;

- Purpose
- Criteria for Abandoning a Private Water Supply Well
- Responsibility
- Decommissioning Report
- Plugging Procedure

PURPOSE

Private water supply wells are removed from service for a number of reasons, including construction of a replacement well, failure of the well to produce safe water, extension of a municipal water system to an area formerly served by individual private wells, or destruction of the building being served. When private wells are removed from service, they are seldom used again and are often forgotten after a property transfer. Over time, they may be covered by vegetation, a parking lot, or a building and they may act as a conduit, or channel, for the vertical movement of contamination from the ground surface to the groundwater or from one aquifer to another.

All abandoned private water supply wells, test holes, and dry or inadequate borings associated with private well installation and not used for water quality monitoring should be plugged in a manner that will permanently prevent vertical movement of water within the borehole, the well, and the annular space between the well casing and the wall of the boring. Unplugged or improperly plugged wells, test holes, and dry or inadequate borings constitute a potential hazard to public health and a danger to ground-water supplies used for drinking water and other beneficial purposes.

Proper plugging will;

(1) eliminate physical hazards

(2) prevent the groundwater from being contaminated by flooding, or the accidental or intentional disposal of waste materials

(3) prevent the intermingling of potable and non-potable groundwater

(4) conserve the yield and hydrostatic head of confined aquifers

(5) prevent localized surface flooding in the vicinity of artesian wells

CRITERIA FOR ABANDONING A PRIVATE WATER SUPPLY WELL

A private water supply well should be abandoned and properly plugged if the well meets any of the following criteria;

(1) construction was terminated prior to completion of the well

(2) the well owner has notified the local Board of Health that the use of the well has been permanently discontinued

(3) the well has, after extended use, been out of service for at least three years

(4) the well is a potential hazard to public health or safety and the situation cannot be corrected

(5) the well is in such a state of disrepair that its continued use is impractical

(6) the well has the potential for transmitting contaminants from the land surface into an aquifer or from one aquifer to another and the situation cannot be corrected

RESPONSIBILITY

It should be the responsibility of the property owner to ensure that all abandoned wells and test holes or borings associated with private well installation are properly plugged. Any person having knowledge of the location of any unplugged abandoned wells, test holes, or dry or inadequate borings should inform the local Board of Health.

One must be a registered well driller to plug abandoned wells, test holes, and dry or inadequate borings. In addition, when an old well is replaced by a new well, it is generally more economical to have the well driller plug the old well at the same time that the replacement is being constructed. In the case of new well construction, it is recommended that any test holes and dry or inadequate borings be plugged before the well driller completes work at the site.

DECOMMISSIONING REPORT

Within 30 days following the completion of the plugging procedure, the registered well driller who plugged the abandoned well, test hole, or dry or inadequate boring must submit a Well Completion Report to the Division of Water Supply Protection and should submit a Decommissioning Report to the owner of the property where the well, test hole, or boring is located. It is recommended that the local Board of Health require that the property owner file a copy of the Decommissioning Report with the appropriate Registry of Deeds or Land Court as part of the chain-of-title. Another copy of the Decommissioning Report should be submitted to the Board of Health. It is recommended that the copy submitted to the Board of Health include the Book and Page reference and the name of the Registry of Deeds where the report was filed or, in the case of registered land, the appropriate Land Court reference.

The following information should, <u>when available,</u> be included in the Decommissioning Report;

(1) name and address of the property owner

(2) name and address of the registered well driller who performed the plugging

(3) reason for abandonment

(4) location of the well, test hole, or boring referenced to at least two permanent structures or, when possible, location coordinates determined by a registered land surveyor or registered civil engineer

(5) all information known about the well, test hole, or boring including but not limited to:

a. depth
b. diameter
c. type of casing

(6) calculations made to determine the volume of the well, test hole, or boring

(7) static water level before plugging

(8) types of plugging material used, including mix specifications

(9) quantity of each type of plugging material used

(10) description of the plugging procedure including, but not limited to, notes regarding;

a. removal of pump and other obstructions
b. removal of screen
c. perforation or removal of casing
d. method used to place plugging material (s)

(11) a copy of the original well driller's report, when available

(12) a copy of the abandonment permit, if a permit is required by the local Board of Health

PLUGGING PROCEDURE

This subsection consists of the following parts:

- Preparation Prior to Placement of Plugging Materials
- Plugging Materials
- Placement of Plugging Materials
- Surface Seal

Preparation Prior to Placement of Plugging Materials

The first step in preparing to plug a well is to obtain information regarding the construction of the well. The construction details are critical for determining whether or not an effective well seal was emplaced during well construction. This, in turn, determines whether or not it is necessary to remove or perforate the well casing prior to emplacement of the plugging materials. A copy of the “Water Well Completion Report" required by the State may be obtained from the well owner or from the Division of Water Resources, which maintains records dating back to 1965. Information on wells constructed prior to 1965 may be available from the well owner or from the well driller. When construction details cannot be obtained, or when there is any doubt as to the integrity of the original well seal, the casing should be removed or perforated, as discussed below.

The next step is to check the well or boring, from the land surface to the completed depth, for any debris or obstruction which may interfere with effective placement of the plugging materials: wells should be disconnected from the water system and all pumping equipment and associated piping should be removed from the well. A variety of fishing tools are used to remove obstructions. For example, threaded taps on the end of a drill rod may be used to screw into the top of a pump or drop pipe; or an over shot (casing with inner teeth), corkscrew, or spear may be used to hook the obstacle. In some instances, it may be necessary to drill, chop or grind up the obstacle and wash it out of the well. Explosives, however, should not be used.

When an effective well seal was not emplaced throughout the entire annular space above the well screen or other intake port during well construction, when construction details are unavailable, or when there is any doubt as to the integrity of the original well seal, the well screen and casing should be removed or perforated in order to plug the full volume of the original borehole.

When it is not feasible to remove the casing of an inadequately sealed well, the casing should be perforated and pressure grouting should be used to place the sealing materials. Perforations should be at least four inches long and should consist of at least four equidistant cuts per row with one row of perforations per linear foot of casing.

Once the well or boring has been cleared of obstructions, the static water level should be measured and recorded. It is important to know where the static water level is because certain types of plugging materials should be placed only above the level of the water in the well or boring.

In order to ensure a proper seal, the volume of grout used to plug the well or boring must equal or exceed the volume of the casing or borehole being plugged. By knowing in advance the minimum volume of grout required to fill the well or hole, it will not be necessary to stop the grouting process in order to prepare more grout. In addition, if the well or boring appears to be filled before the minimum volume of grout has been placed, the contractor knows immediately that the seal is not continuous and is, therefore, inadequate.

The volume of the casing or borehole can be calculated using the cylindrical volume formula, $\pi r^2 h$; where r is the radius of the well or borehole, in feet, and h is the depth. For example, the volume of a well constructed with six-inch diameter casing and a depth of 100 feet can be calculated as follows;

$$\begin{aligned} \text{volume} &= \pi r^2 h \\ &= 3.142 \text{ x } 0.25 \text{ feet x } 0.25 \text{ feet x } 100 \text{ feet} \\ &= 20 \text{ cubic feet} \end{aligned}$$

If neat cement is used, for example, as the sealing material, the number of bags of cement needed to fill the well or boring can be calculated using the assumption that a 94 pound bag of cement plus 5 to 6 gallons of water yields 1.1 cubic feet of material. The following formula can be used to calculate the number of bags of cement needed to fill the well or boring;

$$\text{number of bags of cement needed} = \frac{\text{volume of well or borehole (cubic feet)}}{\text{cubic feet of material produced per bag}}$$

For the preceding example,

$$\text{number of bags of cement needed} = \frac{20 \text{ cubic feet}}{1.1 \text{ cubic feet}} = 18 \text{ bags}$$

Due to borehole irregularities, however, it is advisable to have on hand 25-50 percent more sealant than the calculated volume. Also, when a borehole or uncased well penetrates cavernous limestone or highly fractured bedrock, it should be kept in mind that grout is often lost to the formation.

Plugging Materials

It should be noted that the U.S. Environmental Protection Agency (1975) and the guidelines and regulations for several states recommend or require an abandoned well to be sealed in a manner that restores, to the extent feasible, the hydrogeologic conditions existing before the well was constructed. Some states, for example, recommend that sand and gravel be placed opposite more permeable subsurface zones and clay be placed opposite less permeable zones. While restoration to preexisting hydrogeologic conditions is an admirable goal, it is, in the opinion of the Massachusetts DEP, unattainable in practice.

It is recommended that an abandoned well or boring be completely filled with a grout that, after curing, has a permeability of less than $1x10^{-7}$ cm/sec. There are a variety of grouts which may be used and each has distinct properties which may make one grout more appropriate than another for plugging a given well or boring. The selection of the most appropriate grout or combination of grouts depends primarily on the construction of the well and the geologic and hydrologic nature of the formation or formations penetrated by the well or boring.

Regardless of the type used, the grout;

(1) should be sufficiently fluid so that it can be applied through a tremie pipe from the bottom of the well upward,

(2) should remain as a homogeneous fluid when applied to the subsurface rather than disaggregating by gravity into a two-phase substance,

(3) should be resistant to chemical or physical deterioration, and

(4) should not leach chemicals, either organic or inorganic, that will adversely affect the quality of the groundwater where it is applied.

The following types of grout are acceptable plugging materials. Comments regarding their use are also noted.

(1) **Neat cement grout** is a mixture consisting of one bag (94 pounds) of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A) to not more than six gallons of clean water. Bentonite (API Standard 13A), up to two percent by weight of cement, shall be added to reduce shrinkage. Other additives, as described in ASTM Standard C494, may be used to increase fluidity and/or control setting time. Although one bag of cement to six gallons of water produces a very fluid mixture, it sets up like concrete when it hardens. Neat cement grout may be used in all geologic formations and is ideal for sealing small openings, for penetrating annular space outside of casings, and for filling voids in the surrounding formation. When applied under pressure, it is favored for sealing wells under artesian pressure or borings that penetrate more than one aquifer. Unlike many other grouts, neat cement will not separate into a two-phase substance.

(2) **Sand cement grout** is a mixture consisting of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A), sand, and water in the proportion of one part cement to three or four parts sand, by volume, and not more than six gallons of water per bag (94 pounds) of cement. Up to five percent, by weight, of bentonite (API Standard 13A) shall be added to reduce shrinkage.

(3) **Concrete** is a mixture consisting of Portland cement (ASTM Standard C150, Type I or API Standard 1OA, Class A), sand, gravel, and water in a proportion of not more than five parts of sand plus gravel to one part cement, by volume, and not more than six gallons of water. One part cement, two parts sand, and three parts gravel are commonly used with up to six gallons of water. When a tremie pipe is used to place the concrete, the gravel size should not be greater than 1/3 the inside diameter of the tremie pipe. Concrete may be used in all geologic formations but should never be used below the static water level in the well or boring. Concrete is generally used where extra strength or bulk are required.

(4) **Bentonite** grout is a mixture of bentonite (API Standard 13A) and water in a ratio of not less than one pound of bentonite per gallon of water. Bentonite grout should not be used where it will come in contact with water having a pH below 5.0 or a total dissolved solids concentration greater than 1,000 mg/l, or both.

The advantages and disadvantages of cement-based grouts and bentonite-based grouts are summarized below;

(1) Cement-Based Grouts:

(a) Advantages

- suitable for most types of geologic formations
- easily mixed and pumped
- hard, positive seal; sets up like concrete
- properties can be altered with additives
- proven effective over decades of use

(b) Disadvantages

- mix water must contain less than 500 mg/l of total disolved solids
- separation of constituents (can be overcome by using correct proportion of water to cement)
- high density results in loss to formations
- shrinkage (can be overcome by adding bentonite to the cement slurry)
- saline groundwater may cause flash set
- long curing time
- prompt equipment cleanup essential

(2) Bentonite-Based Grouts:

(a) Advantages

- suitable permeability with high solid grouts
- non-shrinking
- low density
- no curing time required

(b) Disadvantages

- Usage instructions vary with each bentonite product
- difficult mixing
- premature swelling and high viscosity result in difficult pumping
- subject to washout in fractured bedrock
- equipment cleanup difficult
- high density results in loss to formations
- shrinkage (can be overcome by adding bentonite to the cement slurry)
- prompt equipment cleanup essential

Placement of Plugging Materials

The plugging materials should be introduced at the bottom of the well or boring and placed progressively upward to a level approximately four feet below the ground surface. Sealing materials should never be poured from the land surface into the well, borehole, or annular space being sealed because bridging may occur at depth, causing the plug to be discontinuous. An improperly plugged well or boring can be as much of a threat to groundwater quality as an unused open well or boring.

Methods of placement that utilize a grout pipe or tremie tube, either with or without a grout pump, are recommended. To avoid breaking the seal, however, it is important to ensure that the discharge end of the grout pipe or tremie tube is submerged in grout at all times during the placement procedure. Although dump bailers are generally not recommended for placing sealing materials, they may be appropriate when plugging a dug well. Regardless of the method of placement used, care should be taken to prevent segregation or dilution of the sealing materials. When neat cement or cement grout is used, it should be placed in one continuous operation. It should be noted that when bentonite based grout is used, it should be capped by at least six feet of neat cement terminating four feet below the ground surface. The neat cement cap reduces the potential for desiccation cracks in the seal. When the original well seal is inadequate and the casing has been perforated, rather than removed, the well should be pressure grouted in order to ensure that the plugging materials will fill the annular space outside the casing. The entire screened or perforated section of a gravel packed well should also be pressure grouted so that the plug extends into the gravel pack materials. When it is necessary to use pressure grouting, the pressure should be maintained for the length of time that is necessary for the grout to set.

In situations where casing is removed from a well constructed through an unconsolidated formation, it is necessary to introduce the plugging material into the bottom of the hole as the casing is removed. This prevents an excessive amount of material from collapsing into the space at the bottom of the hole. It is recommended that the casing be removed in one to two foot increments followed immediately by pressure grouting of the space at the bottom of the hole.

It should be noted that the entire uncased portion of a bedrock well should be plugged. When zones of lost circulation are encountered when plugging a well or boring that penetrates highly fractured bedrock or cavernous limestone, it is recommended that the grout be pumped until it is certain that it is being lost to the formation. Grouting should then be stopped and the material that has been placed should be allowed to set. Generally, three hours is sufficient time for the grout to set. If grout continues to be lost when placement resumes, three-eighth-inch to one-half-inch diameter pea gravel may be inserted, judiciously, from the surface while simultaneously inserting grout through the tremie pipe. The pea gravel, which floats on top of the cement, should restrict the flow of grout into the formation enough to permit completion of the plugging operation.

For wells completed in artesian aquifers, it is important to ensure that the groundwater is confined to the aquifer in which it occurs. In order to prevent surface or subsurface leakage from the artesian zone, it is recommended that the entire zone be pressure grouted using neat cement. The remainder of the well or boring may be grouted with or without pressure, as warranted by conditions. Flowing artesian wells that are not contained by existing casing should be made static before plugging. For wells in which the hydrostatic pressure producing the flow is relatively low, the well casing may be extended high enough above the artesian pressure surface to stop the flow. For wells in which extension of the casing is not feasible, flow may be restricted by placing an inflatable packer at the bottom of the confining formation immediately above the artesian zone. After the artesian zone has been grouted, the packer should be deflated and removed prior to plugging the remainder of the well. Flow may also be contained by introducing high-specific-gravity fluids at the bottom of the well or boring and filling the hole with fluids until flow ceases. Specific procedures for this method vary with the depth and artesian pressure of the well or boring.

When plugging standard type dug wells, the cover and upper four feet of curbing should be removed before placement of the plugging materials. The curbing may be caved into the well, but only when it is done in a manner that will not prevent any blockage of plugging materials part way down the well. It is recommended that a dump bailer be used to place the plugging materials below the water table in a standard type dug well. The remainder of the well, above the water table, may be plugged using either a dump bailer or a tremie pipe. Use of a dump bailer is not recommended, however, for plugging dug wells constructed with a buried slab.

Surface Seal

In order to allow time for settlement of the plugging materials, the contractor should emplace the surface seal no sooner than 24 hours after the well or boring has been plugged. Before the surface seal is placed, casing remaining in the hole should be cut off. The remaining four feet at the top of the well or boring should then be filled with concrete and the top of the seal formed so as to create a concrete slab above the top of the plugged well or boring. This concrete slab should be at least six inches thick and should be at least two feet greater in diameter than the well casing or borehole wall.

GLOSSARY

Unless the context or subject matter requires otherwise, the following words and phrases shall, for the purposes of this document, have the meanings specified in this section.

Words and phrases used in the present tense include the future; words and phrases used in the masculine gender include the feminine and neuter; and the singular number includes the plural and the singular.

Words and phrases not defined in this section shall have their conventional meanings unless expressly stated otherwise.

Abandoned water well means a well that meets any of the following criteria: (1) construction was terminated prior to completion of the well, (2) the well owner has notified the local Board of Health that use of the well has, after extended use, been permanently discontinued, (3) the well has been out of service for at least three years, (4) the well is a potential hazard to public health or safety and the situation cannot be corrected, (5) the well is in such a state of disrepair that its continued use is impractical, or (6) the well has the potential for transmitting contaminants from the land surface into an aquifer or from one aquifer to another and the situation cannot be corrected.

Alteration means a major change in the type of construction or configuration of a private water system, including but not limited to, adding a disinfection or treatment device, converting a water well with a buried seal to a well with a pitless adapter, extending a distribution system, converting a well using a well pit to a well with a pitless adapter, extending the casing above ground; deepening a well, changing the type of pumping equipment when that requires making new holes or sealing or plugging existing holes in the casing or wall of a well, and repairing, extending or replacing any portion of the inside or outside casing or wall.

Annular space means the space between two cylindrical objects, one of which surrounds the other. For example, the space between the wall of a drillhole and a casing pipe, or between an inner and an outer well casing.

API means American Petroleum Institute.

Aquifer means a geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Artesian aquifer means an aquifer that is bounded above and below by impermeable materials or materials of distinctly lower permeability than the aquifer itself. The water in an aquifer confined in this manner will rise in a drilled hole or well casing above the point of initial penetration (above the bottom of the confining, or impermeable, layer overlying the aquifer).

Artesian well means a well producing from an artesian aquifer. The term includes both flowing wells and nonflowing wells.

ASTM means American Society for Testing and Materials.

AWWA means American Water Works Association.

Bedrock see "Consolidated formation”.

Bentonite means a mixture of swelling clay minerals containing at least eighty-five percent of the mineral montmorillonite (predominantly sodium montmorillonite) which meets the specifications of the most recent revision of API Standard 13A.

Bentonite grout means a mixture of bentonite (API Standard 13A) and water in a ratio of not less than one pound of bentonite per gallon of water.

Casing means an impervious durable pipe placed in a boring to prevent the walls from caving and to serve as a vertical conduit for water in a well.

CMR means *Code of Massachusetts Regulations.*

Community water system means a public water system which serves at least fifteen (15) service connections used by year-round residents or regularly serves at least twenty-five (25) year-round residents.

Concrete means a mixture consisting of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A), sand, gravel, and water in a proportion of not more than five parts of sand plus gravel to one part cement, by volume, and not more than six gallons of water. One part cement, two parts sand, and three parts gravel are commonly used with up to six gallons of water.

Confined aquifer means an aquifer in which the groundwater is under pressure greater than atmospheric pressure: the static water level in a well tapping a confined aquifer rises to a level above the top of the aquifer.

Confining bed means a layer or body of soil, sediment, or rock with low vertical permeability relative to the adjacent aquifers above or below it.

Consolidated formation means any geologic formation in which the earth materials have become firm and coherent through natural rock forming processes. The term is sometimes used interchangeably with the word "bedrock" and includes, but is not limited to, basalt, granite, limestone, sandstone, and shale. An uncased drillhole will normally remain open in these formations.

Contaminant means any physical, chemical, biological, or radiological substance or matter in water.

Contamination means the presence of any physical, chemical, biological, or radiological substance or matter in water at a concentration and for a duration or anticipated duration which, in the opinion of the regulating agency, would present a threat to the public health, using existing federal and state standards and guidelines where applicable.

Cross connection means any physical connection or arrangement between two otherwise separate piping systems, one of which contains potable water and the other water of unknown or questionable safety, whereby water may flow from one system to the other, the direction of flow depending on the pressure differential between the two systems.

Curbing means either precast or poured-in-place, concrete well casing used to construct dug wells.

Domestic water supply means "private water supply."

Drawdown means the difference between the static and pumping water levels.

Drilled well means a well in which the hole is excavated using mechanical means such as rotary, cable tool, or auger rigs.

Drive shoe means a forged or tempered steel collar, with a cutting edge, attached to the lower end of a casing by threading or welding, to protect the lower edge of the casing as it is driven.

Flushing means the act of causing a rapid flow of water from a well by pumping, bailing or similar operation.

Formation means an assemblage of earth materials grouped together into a unit that is convenient for description or mapping.

Groundwater means subsurface water in the zone of saturation.

Grout means a stable impermeable bonding material which is capable of providing a watertight seal.

Grouting means the process of mixing and placing grout.

Hydrofracturing means a process whereby water is pumped under high pressure into a well to fracture the surrounding rock thereby increasing the well yield.

MGL means *Massachusetts General Laws.*

Neat cement grout means a mixture consisting of one bag (94 pounds) of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A) to not more than six gallons of clean water. Bentonite (API Standard 13A), up to two percent by weight of cement, shall be added to reduce shrinkage. Other additives, as described in ASTM Standard C494, may be used to increase fluidity and/or control setting time.

Non-community water system means a public water system that is not a community water system.

Overburden see "Unconsolidated formation.

Person means an individual, corporation, company, association, trust, partnership.

Pitless adapter means a commercially manufactured device which attaches to a well casing and provides watertight subsurface connections for suctions lines or pump discharge and allows vertical access to the interior of the well casing for installation or removal of the pump or pump appurtenances.

Private water supply means a system that provides water for human consumption, if such system has less than fifteen (15) service connections and either (1) serves less than twenty-five individuals or (2) serves an average of twenty-five (25) or more individuals for less than sixty (60) days of the year.

Private water system means "private water supply."

Public water system means a system for the provision to the public of piped water for human consumption, if such system has at least fifteen (15) service connections or regularly serves an average of at least twenty-five (25) individuals daily at least sixty (60) days of the year. Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such a system and used primarily in connection with such system, and (2) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system. A public water system is either a "community water system" or a "non-community water system."

Pumping test means a procedure used to determine the characteristics of a well and adjacent aquifer by installing and operating a pump.

Registered well driller means any person registered with the Department of Environmental Management/Division of Water Supply Protectionto dig or drill wells in the Commonwealth of Massachusetts.

Sand cement grout means a mixture consisting of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A), sand, and water in the proportion of one part cement to three or four parts sand, by volume, and not more than six gallons of water per bag (94 pounds) of cement. Up to five percent, by weight, of bentonite (API Standard 13A) shall be added to reduce shrinkage.

Septic tank means a watertight receptacle which receives the discharge of sewage from a building sewer and is designed and constructed so as to permit the retention of scum and sludge, digestion of the organic matter, and discharge of the liquid portion to a leaching facility.

Static water level means the level of water in a well under non-pumping conditions.

Structure means a combination of materials assembled at a fixed location to give support or shelter, such as a building, framework, retaining wall, fence, or the like.

Surface water means water that rests or flows on the surface of the Earth.

Thermoplastic casing means ABS (acrylonitrile-butadiene-styrene), PVC (poly-vinyl chloride) or SR (styrene rubber) casing specified in the most recent revision of ASTM Standard F480.

Tremie pipe means a device, usually a small diameter pipe, that carries gravel pack or grouting materials to the bottom of a drillhole or boring and which allows pressure grouting from the bottom up without introduction of appreciable air pockets.

Unconfined aquifer means an aquifer in which the static water level does not rise above the top of the aquifer.

Unconsolidated formation means any naturally occurring uncemented, unlithofied material such as sand, gravel, clay, or soil.

Water table means the upper surface of the zone of saturation in an unconfined formation at which the pressure is atmospheric.

Watertight means a condition which does not allow the entrance, passage or flow of water or other fluids under normal operating conditions.

Watertight casing means a water well casing that has a wall thickness of 1/8 inch or more, has no seams or has welded seams, and has sections that can be joined together by watertight threads, by a weld, rubber gasket, or by cement that is not limestone or clay based that seals the well against the entrance of surface water into the groundwater.

Watertight construction means cased and grouted construction through firm formations like clay or rock. Through granular material like sand or gravel, it means that the casing pipe is of approved quality and assembled watertight.

Well development means a procedure consisting of the removal of fine sand and drilling fluid from the water bearing sand, gravel, or rock materials opposite the well screen.

Well vent means an outlet at the upper end of a well casing or basement end of a non-pressure conduit to allow equalization of air pressure in a well but at the same time so constructed as to prevent entry of water and foreign material into the well.

Yield means the quantity of water per unit of time which may flow or be pumped from a well under specified conditions.

Zone of saturation means the zone below the water table in which all interstices are filled with groundwater.

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. Requirements for the proper construction of wells vary with the character of the subsurface materials and provisions applicable under all circumstances cannot be
As conditions warrant and with the approval of the regulating agency, the construction details of this Table may be adjusted.

[1] The term "pumping level" refers to the maximum drawdown occurring in the well during pumping, determined to the best knowledge of the water well contractor, accou
usual seasonal fluctuations of the static water level and drawdown level.

[2] "Granite" and "trap rock" are general terms commonly used by well drillers to describe several different types of igneous and metamorphic rock. "Limestone" is a
commonly used by well drillers to describe both limestone and dolomite.

Adapted from Wisconsin Administrative Code NR 112, "Register," October 1985, No. 358 and from "Recommended State Legislation and Regulations," Dept. of Health, Edu
and Welfare, Public Health Service, Washington, D.C., July 1965.